UPPER ORDOVICIAN TRILOBITES FROM CENTRAL NEW SOUTH WALES

by B. D. WEBBY

ABSTRACT. Twelve trilobite species are described and illustrated from Upper Ordovician (Caradoc) successions of central New South Wales. Included among the forms is a new scutelluid genus, *Heptabronteus*, with two new species, *H. atavus* (type species) and *H. major*, and five other new species, *Toernquistia arguta*, *Parkesolithus dictyotos*, *Sphaerocoryphe exserta*, *Amphilichas nasutus*, and *A. encyrtos*. A discussion of relationships between *Heptabronteus* and other scutelluid genera is presented. *Triarthrus* is recorded for the first time from New South Wales, and evidence for dimorphism in the raphiophorid, *Malongullia oepiki* Webby, Moors, and McLean, 1970, considered. The stratigraphical distribution of the faunas is described, and zoogeographical relationships discussed. The New South Wales fauna is included in the *Heptabronteus–Pliomerina* province of Australia, South-East Asia, and Kazakhstan, one of two or more separate provinces within the much larger, band-like, probably equatorial, Remopleuridid realm of the Caradoc. The faunas are interpreted broadly as occurring in an island-arc tectono-environmental setting. They have been differentiated into a possible benthonic assemblage in the shallow-water carbonate rise facies, and into inferred benthonic and pelagic associations in the deeper, graptolitic shale slope and trough facies.

EARLIER descriptions of the Upper Ordovician trilobites from central New South Wales were given by Webby, Moors, and McLean (1970), Campbell and Durham (1970), Webby (1971), and Webby (1973). This paper concludes the description of the faunas based on collections in the Department of Geology and Geophysics, University of Sydney.

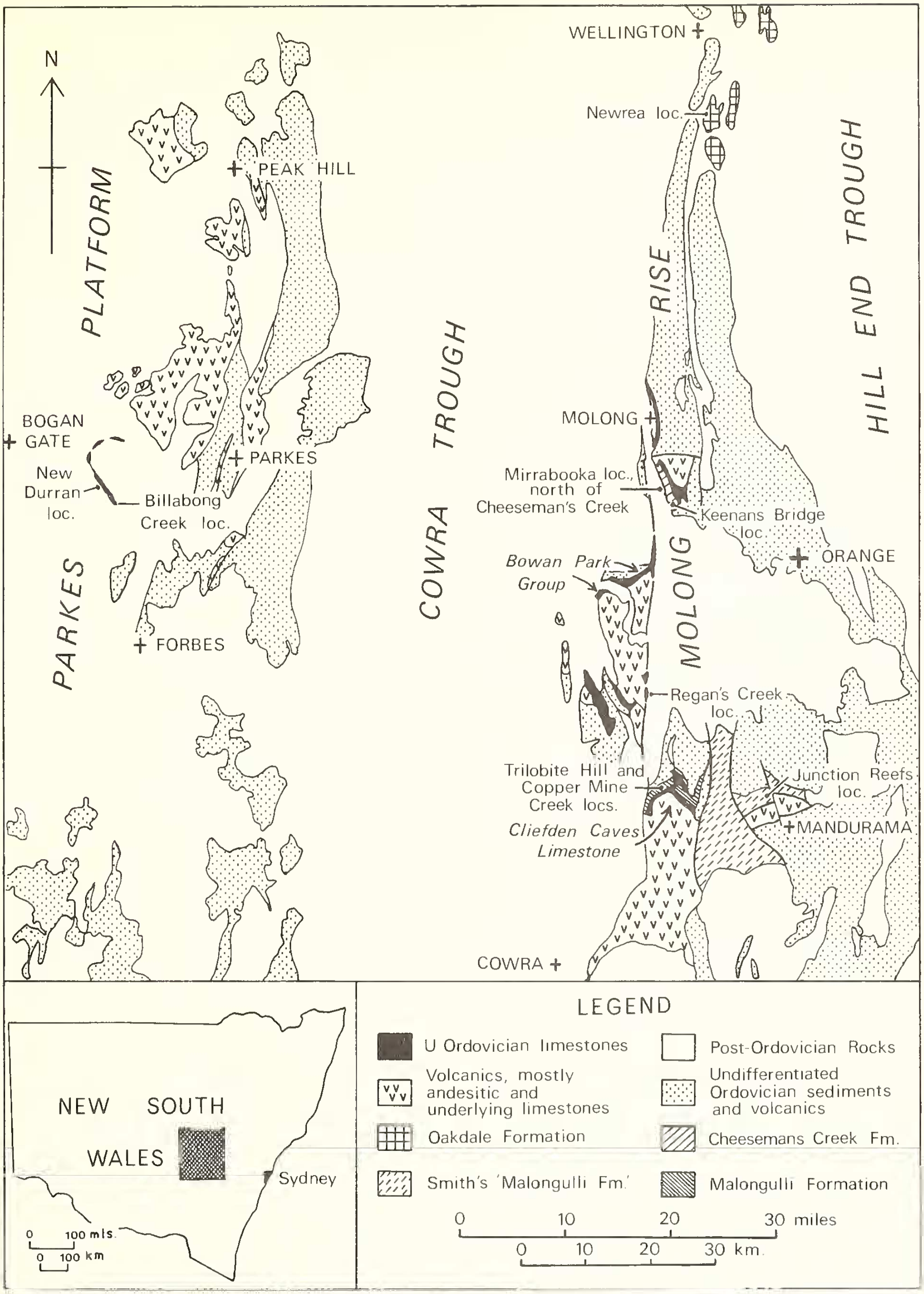
DISTRIBUTION

The distribution of trilobites in the Upper Ordovician successions of central New South Wales is represented in text-fig. 1. Locality details are given in previous papers and in the systematic descriptions of these pages. Most of the localities occur within the areas of the geotectonic 'highs', the Molong Rise and the Parkes Platform (text-figs. 2 and 4), in off-shore parts of the Lachlan Geosyncline (Packham 1969). In both regions extensive outpourings of Lower or Middle Ordovician andesitic volcanics accumulated on the sea floor, and seem to have built up 'highs' within the geosyncline. These volcanic piles apparently became emergent and planated, providing platforms for the deposition of shallow-water carbonates. It remains to be established whether in the Upper Ordovician a deeper-water shale succession was being deposited in the Cowra Trough between contemporaneous limestone successions of the Parkes Platform and Molong Rise, or whether the carbonates originally formed on a single, extensive Parkes–Molong volcanic rise (text-fig. 4). Packham (1967; 1969, p. 217) has indicated that Upper Ordovician graptolite deposits occur in the Cowra Trough at Tomingley but, considering their location 40 miles (64 km) north of Parkes, they may not be strictly assignable to the trough. Scheibner (1972) has claimed that the Cowra Trough originated by splitting of the Parkes–Molong volcanic rise in the early Silurian. To the west of the Parkes Platform, late Ordovician quartz-rich greywackes and slates were deposited in the Wagga Trough, a possible

[Palaeontology, Vol. 17, Part 2, 1974, pp. 203–252, pls. 28–34.]

FACIES	CARBONATES						GRAPTOLITIC SHALES						
TECTONIC ELEMENT	P.P.	Molong Rise					P.P.	Molong Rise				H.E.T.	
FORMATION	Unnamed limestone, Billabong Creek	Bowan Park Group			Cliefden Caves Limestone		Unnamed shales, New Durran	Malongulli Formation			Cheesemans Creek Formation near Keenans Bridge	Oakdale Fm., near Newrea	'Malongulli Fm.', Junction Reefs
DISTRIBUTION		Ballingoole Formation	Quondong Formation	Daylesford Formation	Upper part	Lower part		Cliefden Caves (type area)	Regan's Creek area	North of Cheesemans Creek (derived)			
Geragnostus? sp												vr	
Shumardia sp												vr	r
Triarthrus sp											r		
Remopleurides saenuros[1]	mc												
R. exallos[2]								c		r			
R. acer						mc							
R. sp. A[1]	r												
R sp B[2]										vr			
R sp C										vr?			
R sp. indet.		r											
Pseudobasilicus? fortis						vc							
P? sp. A	mc		mc										
asaphid gen. et sp indet		r											
Illaenus (Parillaenus)? incertus		vc											
I. (P.)? sp. A										vr			
Heptabronteus atavus						c							
H major								c		r			
Toernquistia arguta										r			
harpid gen. et sp nov	r				r								
proteid gen et sp. indet		r											
Parkesolithus gradyi							c						
P dictyotos								mc		c			
trinucleid gen et sp indet		r											
Malongullia oepiki (dimorph A)[3]								vc		r			
M. oepiki (dimorph B)[3]								r		mc			
Sphaerocoryphe exerta	r												
Pliomerina austrina	vc		c		c								
P prima				mc		vc							
Encrinuraspis optimus								mc	r	vr			
Encrinuraspis? sp A	r		r										
E.? sp. B				vr									
encrinurid gen et sp indet		r											
Amphilichas nasutus	r												
A encyrtos			r										

TEXT-FIG. 1. Chart showing trilobite distribution in Upper Ordovician of central New South Wales. The three dimorphs in the faunas are numbered 1, 2, and 3. Relative abundances at the best collecting locality of the particular unit are given by symbols: vc, very common; c, common; mc, moderately common; r, rare; vr, very rare. P.P., Parkes Platform. H.E.T., Hill End Trough.



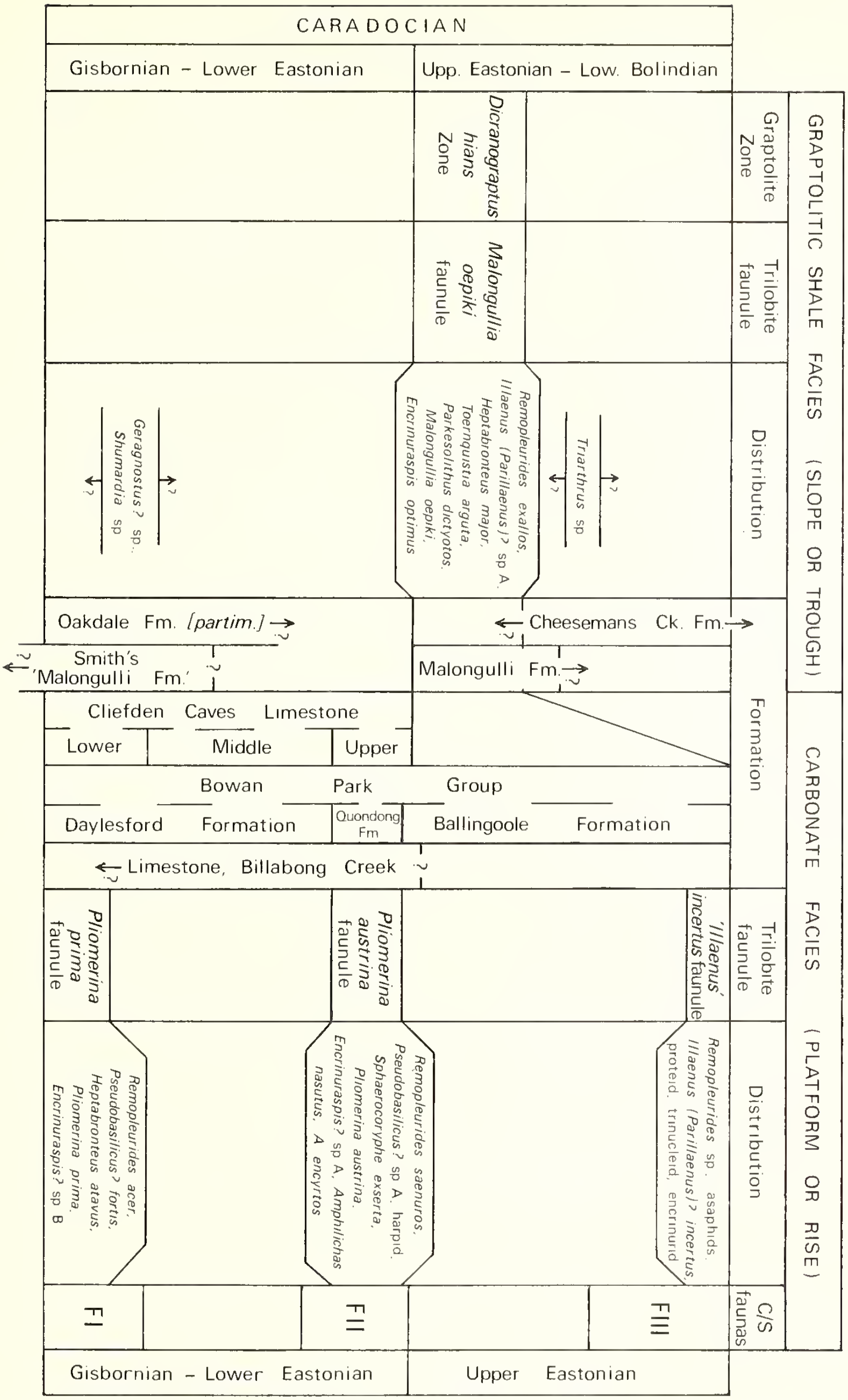
TEXT-FIG. 2. Generalized map showing Ordovician geology of central New South Wales, and principal trilobite localities. The major tectonic elements represented are situated in the eastern part of the Lachlan Geosyncline. Note occurrences of Upper Ordovician limestones on the Parkes Platform and Molong Rise, formed in off-shore parts of the geosyncline. Based on data from the Macquarie 1:500,000 Geol. Series Sheet, First Edition, 1970.

marginal sea (Packham and Falvey 1971). The Hill End Trough (text-fig. 4) to the east of the Molong Rise has a history of andesitic volcanism predating the earliest-determined graptolites of Darriwilian (Middle Ordovician) age (Smith 1966). The Middle–Upper Ordovician deposits comprise mainly shales, cherts, greywackes, tuffs, and andesitic volcanics.

Thick limestone successions are developed on the Parkes Platform (unnamed limestone at Billabong Creek), and on the flanks of the Molong Rise (western side, typified by 560 m-thick Bowan Park Group, and eastern side by Cliefden Caves Limestone, some 250 m thick). In the thickest, continuous limestone succession at Bowan Park, three biostratigraphically distinct trilobite assemblages are recognized. Only the first and second occur in the Cliefden Caves Limestone, and only the second, in the unnamed limestone at Billabong Creek. These assemblages are named faunules after the most common constituent species. They comprise the *Pliomerina prima*, *P. austrina*, and '*Illaenus*' *incertus* faunules (text-figs. 3, 4), and correlate reasonably well with the stromatoporoid/coral faunas I, II, and III introduced previously (Webby 1969).

Directly overlying the Cliefden Caves Limestone is the Malongulli Formation, a shale and siltstone succession containing in the lower part an abundant sponge spicule, graptolite, trilobite, and brachiopod fauna. The graptolites determined by Moors (1970) suggest the Zone of *Dicranograptus hians*, that is, Upper Eastonian in terms of the Victorian stages. The Zone of *D. hians* seemingly corresponds to the Zone of *D. clingani* in Europe (Strachan 1972). The rich trilobite assemblage, the *Malongullia oepiki* faunule (text-fig. 3), is recognized in the type area near Cliefden Caves, in the Regan's Creek area, where it lies above the Regan's Creek Limestone, and further north, in the Cheeseman's Creek area. In this latter area Sherwin (1971) has interpreted the occurrences of shales of the Malongulli Formation and of limestones near Mirrabooka homestead as exotic blocks in the Upper Silurian Wallace Shale. It seems unlikely, judging from the size of some of the blocks and the apparent ordered arrangement of shale and limestone occurrences, that they have been transported far from their original sites of deposition. With the sudden change of facies from the carbonates of the Cliefden Caves Limestone type to the graptolitic shales of Malongulli Formation type on the eastern flank of the Molong Rise, there is the appearance of a completely different trilobite fauna. At least three genera, *Toernquistia*, *Parkesolithus*, and *Malongullia*, make their first appearance in this shaly, possibly 'deeper-water', facies, and all the species are quite distinct from those of the preceding carbonates. The transgression of 'deeper-water' facies over the eastern flank of the rise did not continue on to the western flank where carbonate deposition continued uninterrupted (text-fig. 4), with the accumulation of the Ballingoole Formation (Bowan Park Group), and the upper parts of the Cargo Creek and Canomodine Limestones. Limestone breccias derived from these adjacent carbonate platforms occur in the 'deeper-water' shales of the Malongulli Formation.

Sherwin (1971) introduced the Cheesemans Creek Formation for about 900 m of interbedded siltstone, andesites, tuffs, and greywackes overlying the Reedy Creek Limestone in the Cheeseman's Creek area, and cropping out in a broad belt to the east of the occurrences of exotic blocks in the Wallace Shale. There is a broad correlation of the Reedy Creek Limestone with the Cliefden Caves Limestone (Webby



TEXT-FIG. 3. Correlation of the Upper Ordovician (Caradoc) trilobite faunal successions in graptolitic shale and carbonate facies of central New South Wales. C/S faunas, coral/stromatoporoid faunas of Webby 1969.

1969). The graptolite occurrences in the Cheesemans Creek Formation suggest an Eastonian and Bolindian age (Sherwin 1971, p. 207). It therefore correlates with the Malongulli Formation and the overlying Angullong Tuff of the Cliefden Caves area. The occurrence of *Triarthrus* sp. in the beds of the Cheesemans Creek Formation near Keenan's Bridge, lying stratigraphically near the middle of the formation, is possibly about the Eastonian–Bolindian boundary or Lower Bolindian age. It probably lies stratigraphically somewhat higher than the trilobite occurrences in the Malongulli Formation (text-fig. 3). *Triarthrus* is not known elsewhere in beds younger than the Caradoc. This particular occurrence would therefore seem, from generalized correlation, to be of late Caradoc age.

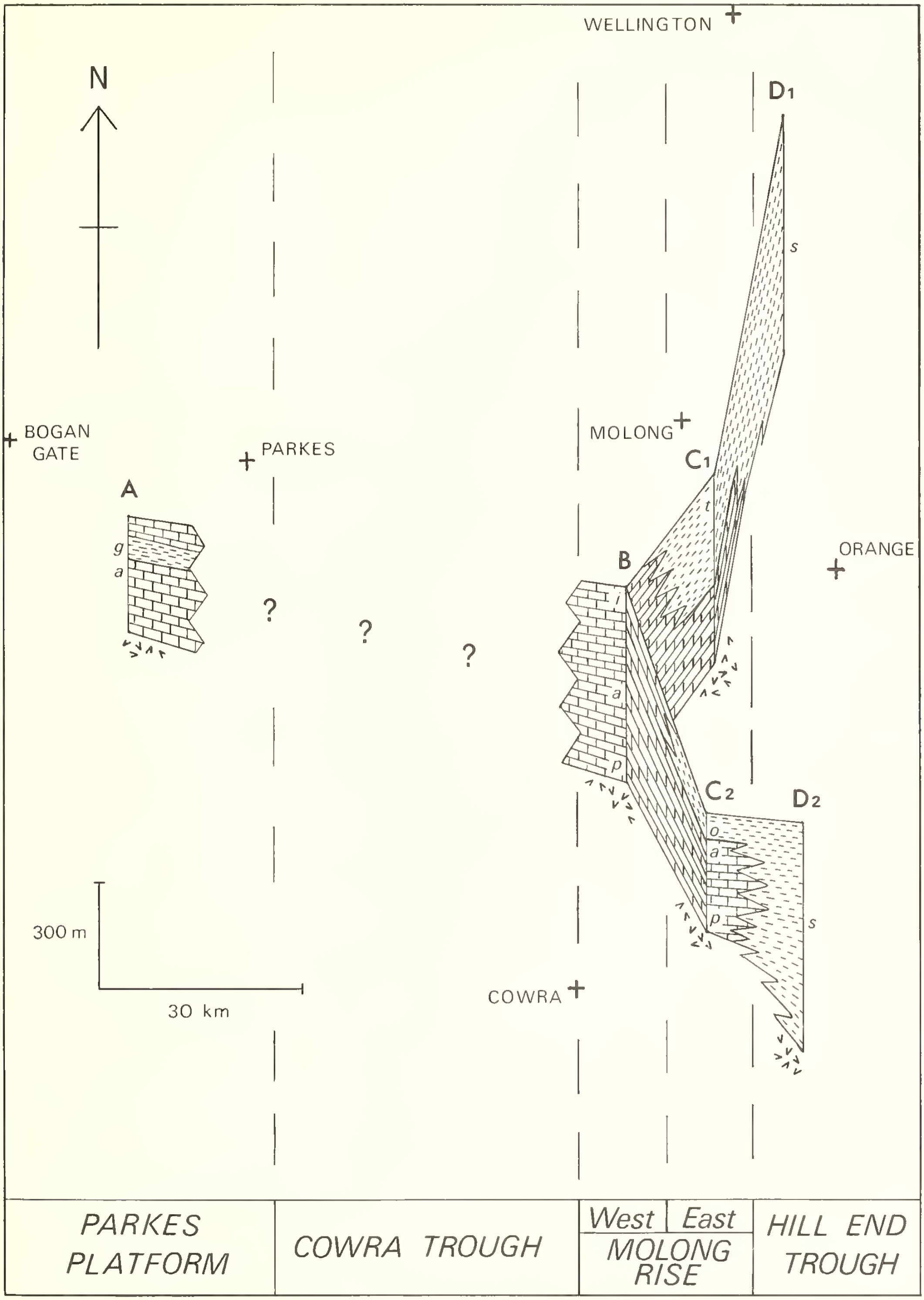
As already mentioned (Webby 1973), it is likely that the records of *Shumardia* and *Geragnostus*? in the Oakdale Formation near Newrea, and of *Shumardia* in Smith's 'Malongulli Formation' at Junction Reefs, near Mandurama, are significantly older, possibly Gisbornian occurrences (text-fig. 3). Part of these shale successions may have been laid down essentially contemporaneously with the lower part of the Cliefden Caves Limestone and other equivalent limestones on the eastern flank of the Molong Rise, in deeper waters of the Hill End Trough to the east (text-fig. 4).

On the Parkes Platform, some 50 miles (80 km) to the west (text-fig. 2), another similar succession of limestones is succeeded by graptolitic shales. Although the detailed stratigraphy remains to be fully elucidated, there are two localities containing trilobites, one in the upper half of the limestone at Billabong Creek (Packham 1967) and the other in the stratigraphically higher shales near New Durran homestead (Campbell and Durham 1970). The rich, silicified trilobite assemblage in the limestone belongs to the *Pliomerina austrina* faunule, and is probably about Lower Eastonian in age (text-fig. 3). The overlying shales containing the trinucleid *Parkesolithus gradyi* Campbell and Durham, 1970 have been considered, from their associated graptolites, to have an Eastonian age by Campbell and Durham, and a Bolindian or less probably an Eastonian age by Sherwin (1970).

ZOOGEOGRAPHY

Whittington (1966) originally included the New South Wales 'Caradoc' trilobites in the '*Encrinurella*' fauna of South-East Asia and Australia. The fauna was subsequently renamed the *Pliomerina* fauna (Webby 1971) because *Encrinurella* could not be confirmed in 'Caradoc' successions of the Australian region. According to this conception, it was taken to represent a faunal province, and to include Australia, South-East Asia (including South Korea), and Kazakhstan. From a more recent analysis of the world-wide distribution of Caradoc trilobites, Whittington

TEXT-FIG. 4. Diagram showing generalized lateral interrelationships of the carbonate and graptolitic shales facies overlying andesitic volcanics in the region between the Parkes Platform and the Hill End Trough, central New South Wales. Sections: A, Billabong Creek–New Durran; B, Bowan Park; C_1, Cheeseman's Creek; C_2, Cliefden Caves; D_1, Newrea; D_2, Junction Reefs. Faunules: *p*, *Pliomerina prima*; *a*, *P. austrina*; *i*, *Illaenus* (*Parillaenus*)? *incertus*; *o*, *Malongullia oepiki*. Occurrences: *s*, *Shumardia*; *t*, *Triarthrus*; *g*, *Parkesolithus gradyi*. Note that the thicknesses are very approximate, and that the graptolitic shale facies includes horizons of tuff and, in the sections C_1, D_1, and D_2, volcanics.


WELLINGTON
N
D1
s
BOGAN GATE
PARKES
MOLONG
C1
A
t
g
a
B
ORANGE
?
?
?
i
a
p
C2
D2
o
a
p
s
300 m
30 km
COWRA
PARKES PLATFORM
COWRA TROUGH
West
East
MOLONG RISE
HILL END TROUGH

and Hughes (1972) have considered only two provinces to be clearly recognized—a small, rather restricted *Selenopeltis* province (including southern Europe and North Africa) and a vast Remopleuridid province (covering North America, northern Europe, most of Asia, and Australia), the latter having essentially an equatorial distribution. The few Caradoc trilobites known from South America and New Zealand have uncertain affinity. South-East Asia and Australia are suggested to be a possible subprovince of the Remopleuridid province. In their palaeogeographical reconstructions, Kazakhstan which has species of *Pliomerina*, and North-East Asia which has not, are placed together, hugely displaced from South-East Asia and Australia.

Considering the New South Wales 'Caradoc' fauna in general terms, three out of a total of fifteen genera—*Parkesolithus*, *Malongullia*, and a new harpid—are believed to be endemic (Table 1). Zoogeographical relationships are closest to South-East

TABLE 1. Caradoc zoogeographical relationships and endemism of the New South Wales genera. X = confirmed; ? = possible.

	Endemic elements	Zoogeographical relationships					
		SE. Asia	Kazakhstan	North Europe	North America	New Zealand	South America
Remopleurides		X	X	X	X		
Amphilichas		X	X	X	X		
Sphaerocoryphe		?	?	X	X		
Pseudobasilicus?		X	?	?			
I. (*Parillaenus*)?		?	?	?			
Toernquistia		?	X	X	?		
Heptabronteus		?	X				
Pliomerina		X	X				
Encrinuraspis		X					
Parkesolithus	X						
Malongullia	X						
harpid gen. nov.	X						
Geragnostus?		?	?	?			
Shumardia		?	X	X			
Triarthrus		?	?	X	X	X	X

Asian and Kazakhstan regions. The genera *Pliomerina* and *Encrinuraspis* occur in South-East Asia, and *Pliomerina* and *Heptabronteus* in Kazakhstan. The presence of *Toernquistia* and possibly *Pseudobasilicus* and *Illaenus* (*Parillaenus*) suggests a less strong connection with northern Europe. *Toernquistia* may have had a wider distribution with its possible occurrences in Idaho and Nevada (Churkin 1963; Ross and Shaw 1972). The records of *Remopleurides*, *Amphilichas*, and *Sphaerocoryphe* imply a relationship within the world-wide, perhaps equatorial, Remopleuridid province (or, as I would prefer, realm). It seems desirable, therefore, to regard the New South Wales 'Caradoc' fauna, with its close relationships to South-East Asia and Kazakhstan (Table 1), as belonging to the *Heptabronteus–Pliomerina* province, situated within the much larger, band-like, 'equatorial' Remopleuridid realm. The province appears to include only shelf margin-open sea faunas (Palmer 1972).

For more complete evaluation of the zoogeographical relationships it is necessary to take account of the facies control, mode of life, and tectono-environmental settings of the faunas. Of the fifteen families occurring in the entire New South Wales fauna, only five—the remopleuridids, scutelluids, illaenids, trinucleids, and encrinurids—are found in both carbonate and graptolitic shale facies. Of the genera, *Remopleurides*, *Heptabronteus*, *Illaenus* (*Parillaenus*)?, and possibly *Encrinuraspis* are found in both facies, though only *Remopleurides* and *Heptabronteus* are well represented in both (Table 2). At the species level there are no facies breakers.

TABLE 2. Number of species represented in carbonate and graptolitic shale facies of the Gisbornian–Eastonian succession of central New South Wales. Species of *Triarthrus*, *Shumardia*, and *Geragnostus*? are inferred to have had a mainly pelagic mode of life, whereas all others are thought to have been benthonic in the adult stage. Endemic elements of the fauna are indicated by asterisks.

	Platform or rise (carbonates)	Slope and trough (graptolitic shales)
Remopleurides	3	2
Amphilichas	2	—
Sphaerocoryphe	1	—
Pseudobasilicus?	2	—
Illaenus (*Parillaenus*)?	1	1
Toernquistia	—	1
Heptabronteus	1	1
Pliomerina	2	—
Encrinuraspis	2?	1
*Parkesolithus**	—	2
*Malongullia**	—	1
harpid gen. nov.*	1	—
Geragnostus?	—	1
Shumardia	—	1
Triarthrus	—	1

The carbonate facies of the shallow-water platform or rise exhibits a fauna interpreted as including only benthonic elements. The abundant cosmopolitan genus *Remopleurides* is represented in both carbonate and graptolitic shale facies, but is not regarded as a pelagic element because no individual species of the genus is found in both facies. *R. saenuros* Webby from the unnamed limestone at Billabong Creek occurs in an only slightly older horizon than *R. exallos* Webby from shales of the Malongulli Formation in the Cliefden Caves and Cheeseman's Creek areas (text-figs. 1, 3), yet is markedly different from it. The New South Wales species of *Remopleurides* preserved in shales typically possess a much finer pattern of ornamentation than those occurring in the limestones (Webby 1973). If they were pelagic forms one would expect to find a much less well-defined facies control of the individual species.

Two distinct types of association are represented in the deeper, graptolitic shale facies. The first is best developed in shales at the base of the Malongulli Formation, in beds directly overlying the Cliefden Caves Limestone (text-fig. 4, section C_2), considered to have formed in deeper waters of the slope immediately adjacent to the rise. Among elements of the fauna are sighted, zoogeographically relatively restricted to endemic forms, including species of *Malongullia*, *Parkesolithus*, *Encrinuraspis*, and *Heptabronteus*. This zoogeographically restricted fauna is inferred to have had a benthonic mode of adult life. The second type of association occurs in thick, interbedded graptolitic shale, chert, tuff, and volcanic sequences (text-fig. 4, sections C_1, D_1, and D_2). It comprises relatively small, mainly blind, relic elements of long-lived, cosmopolitan stocks, including species of *Shumardia*, *Geragnostus*?, and *Triarthrus*. This is typically an open-sea or oceanic fauna, with representatives of agnostids (Robison 1972) and olenids (Öpik 1963) regarded as having had a pelagic mode of life. The elements of this fauna may have lived in even deeper waters of the trough. *Triarthrus*, the last of the olenids, is recognized as an extremely widespread stock in dark shales of Caradoc age, occurring throughout the Remopleuridid realm and also in New Zealand (Skwarko 1962) and South America (recorded by Harrington and Leanza 1957, as *Porterfieldia* Cooper, 1953, which was shown to be a junior synonym of *Triarthrus* by Whittington 1957, and an invalid genus by Whittard 1961). *Shumardia* and *Geragnostus* are also widespread and long-ranging genera, though apparently much less common in beds above the base of the *Nemagraptus gracilis* Zone. Whittington (1966) has previously noted these forms to be geographically widely distributed elements.

In the inferred benthonic assemblage in the shales of the slope, all the generic components, apart from *Remopleurides*, are restricted to having relationships with South-East Asia, Kazakhstan, or northern Europe, or are endemic. In the fauna of the carbonate facies of the adjacent rise, on the other hand, there is a markedly higher proportion of widespread elements of the Remopleuridid realm, with occurrences of *Remopleurides*, *Amphilichas*, and *Sphaerocoryphe*, and possible northern European relationships suggested by records of forms tentatively assigned to *Pseudobasilicus* and *Illaenus* (*Parillaenus*). The shale fauna of the slope has two endemic genera in a total of seven inferred benthonic genera, and the carbonate fauna of the rise, one endemic genus in a total of nine genera (Table 2). In terms of abundances of generic components at particular localities, not greatly different in age, the richly fossiliferous representatives of the shale type at Trilobite Hill and near-by Copper Mine Creek may be compared with a similarly rich occurrence of the carbonate type at Billabong Creek, and demonstrates an even greater degree of endemism in the shales of the slope (Table 3). The overall percentage of endemism based on abundances of generic components is 47% in the shale, and 10% in the carbonate type. The benthonic assemblage in the shales of the slope is not significantly less diverse than the fauna in the carbonates of the rise, but it has a markedly higher proportion of endemic elements.

These faunas of off-shore parts of the Lachlan Geosyncline are considered to have occupied the tectono-environmental setting of an island-arc type of geosyncline (Mitchell and Reading 1969), separated from the continental mass by the intervening Wagga Trough, a possible marginal sea like the present Sea of Japan (Packham and Falvey 1971). The fauna in the carbonates of the rise includes a number of forms which suggest ease of widespread dispersal within the Remopleuridid realm, probably along migration routes in shallow seas bordering island chains and fringing continental masses, aligned east–west, in low latitudes, and with no significant climatic barriers (Valentine 1971). The presence of geographically more restricted

TABLE 3. Percentage of endemism assessed on the basis of abundances and diversity of generic components in faunas of representative occurrences of shale and limestone facies. Most abundant element of fauna scores 5 points; moderately common, 4 points; common, 3 points; rare, 2 points; and very rare occurrence, 1 point. Abundance scores for the one, two, or three genera exhibiting endemism or a particular zoogeographical relationship are shown in columns A–D. Number of endemic genera or genera showing particular zoogeographical relationships given in brackets.

Lithology	Locality	A Endemic	B SE. Asia and Kazakhstan	C Northern Europe	D Widespread in Remopleuridid realm	Total abundance score and total number of genera in brackets	Percentage of endemism in terms of abundance score. Percentage of endemic genera in brackets
Shale	Trilobite Hill and Copper Mine Creek	9(2)	7(2)	—(—)	3(1)	19(5)	47(40)
Limestone	Billabong Creek	2(1)	7(2)	4(1)	8(3)	21(7)	10(14)

relationships in the inferred benthonic slope fauna seems to imply less easy routes of migration within the deeper slope environments. No endemic elements of the deeper shale environments are known to have invaded the shallow-water environments of the rise. The close faunal relationships of the New South Wales island-arc 'benthonic' assemblages of both shale and carbonate facies with those of South-East Asia and Kazakhstan in Upper Ordovician times implies either former close links along a continuous chain of islands, or a much nearer association of the continental blocks of Australia, and South-East and Central Asia than at present.

DIMORPHISM

Although it remains virtually impossible to prove sexual dimorphism in trilobites, even where different forms are found together on the same bedding surfaces, there is, nevertheless, growing circumstantial evidence for dimorphism in some groups, with a steadily growing number of references to particular examples (Öpik 1958; Whittington 1959, 1963, 1965; Hu 1964, 1971; Selwood 1965; Selwood and Burton 1969; Clarkson 1969; Webby 1973). One of the most convincing examples is that given by Öpik (1958) for a species of *Redlichia*, *R. forresti* (Etheridge) from the lowermost Middle Cambrian of Western Australia and the Northern Territory. Öpik recognized two distinct forms in *R. forresti*, a common, large (average length, 100 mm), slender 'female' form with slender dorsal spines on the axis of the thorax, short pleural spines, an unusual pygidium with a poorly differentiated axis and pygidial doublure restricted to the lateral flanks, and a rare, small (15 mm in length) 'male' with stout dorsal spines, long pleural spines, and a pygidium having a normal annulated axis and a doublure continuous beneath the border. The possibility of dimorphism in the New South Wales representatives of *Remopleurides* has been discussed recently (Webby 1973).

In the shales of the Malongulli Formation at two different localities, the raphiophorid, *Malongullia oepiki* Webby, Moors, and McLean, 1970, has been found to be associated in the same beds with a much larger form exhibiting a *Malongullia*-type cephalon and thorax, but much expanded pygidium. At the Copper Mine Creek (and near-by Trilobite Hill) locality, near Cliefden Caves, the smaller *M. oepiki* is much more common, and in the Mirrabooka locality of the Cheeseman's Creek area, though the sample is small, there is a slight dominance of the larger form with the expanded pygidium. The two types clearly seem to represent dimorphs but have been described as separate morphological forms in the following pages (Pl. 30, fig. 12; Pl. 31, figs. 4–12; Pl. 32, figs. 1–6). The larger form is possibly the female of the species and is referred to as *M. oepiki* (dimorph B). It is on average four times larger than the possible male, *M. oepiki* (dimorph A), the original type material of the genus and species (Webby, Moors, and McLean 1970). On the cephalon of dimorph B, the preglabellar field is longer (sag. and exsag.) and exhibits a pair of small tubercles, and the posterior border is longer (exsag.) and more flattened. Anastomosing ridges (perhaps caecae) on the antero-lateral parts of the fixed cheek of dimorph B are not seen in dimorph A. The pygidium of dimorph B is fundamentally distinct in being much longer, rounded posteriorly and in having 16–20 axial rings, eight–ten pleural ribs, more conspicuous muscle attachment areas with up to seven pairs of oval muscle scars connected across the ring furrows, nine pairs of isolated scars on axial segments behind, and a suggestion of pygidial caecae in the posterior part of the pleural fields and behind the rounded tips of the axis (Pl. 31, figs. 4, 10–11; Pl. 32, figs. 5–6). In the smaller dimorph A, in contrast, the pygidium is shorter, subtriangular, it has 8–9 axial rings, 5 pleural ribs, and 6–7 pairs of transversely elongated apodemal pits with pairs of muscle scars confined to just in front of apodemal pits of the first two axial rings. The first pair of muscle scars are connected across the ring furrow, and the second pair, isolated (Pl. 31, fig. 12; see also Webby, Moors, and McLean 1970, pl. 125, figs. 1, 5–7, 11–12).

SYSTEMATIC DESCRIPTIONS

Family OLENIDAE Burmeister, 1843
Genus TRIARTHRUS Green, 1832

Type species. T. beckii Green, 1832.

Triarthrus sp.

Plate 32, fig. 13

Material. One specimen (SUP 37999) from the Cheesemans Creek Formation in the disused quarry just east of Keenan's Bridge, Cheeseman's Creek area (Sherwin 1971). Another specimen (MMF 18638) of part of thorax and pygidium from the same locality and horizon is in collections of the Geological and Mining Museum, Geological Survey of New South Wales.

Description. Only part of lateral border of left free cheek known. Thorax of fifteen segments; axial furrows deep, prominent; axis gently convex, slightly more than one-third total width, tapering very gently backward; each axial ring with large median tubercle and scattered very tiny tubercles to either side of it; deeply indented articulating furrows, especially laterally, and well-developed articulating half rings, at least two-thirds length (sag.) of axial rings. Deep, prominent pleural furrows directed outward and backward from inner, anterior corner of pleurae towards outermost tip. Inner part of pleurae short (tr.), transverse, about one-third total width of pleurae; outer part of pleurae, beyond fulcrum, relatively wide, directed outward and backward. Pygidium small, transversely elongated, with flattened outline of posterior margin medially; four (or possibly five) axial rings and small terminal piece; four pairs of pleural ribs; there appears to be a median tubercle on anterior axial ring of pygidium.

Remarks. There is considerable resemblance between the thorax and pygidium of the holaspis of *Triarthrus eatoni* (Hall) from the Holland Patent Shale of Trenton, New York (Whittington 1957) and that of the incomplete Cheeseman's Creek material. However, *T. eatoni* exhibits sixteen thoracic segments, and a relatively narrower axis with each axial ring apparently smooth apart from the slightly smaller median tubercle.

In Australasia, *Triarthrus* has previously been recorded by Gilbert-Tomlinson (1961), and Whittington and Hughes (1972, p. 272) from the Llanvirn of the Canning Basin, and from the basal Gisbornian (Lower Caradoc) of New Zealand (Skwarko 1962).

Family SCUTELLUIDAE Richter and Richter, 1955
Genus HEPTABRONTEUS gen. nov.

Type species. H. atavus sp. nov.

Diagnosis. Scutelluid genus with forwardly widening glabella and axial furrows deflected outwards, apparently dying out anteriorly; no clearly differentiated preglabellar area on anterior margin; large, raised, curved eyes situated posteriorly; relatively broad area of fixed cheek between outwardly diverging anterior branch of facial suture and axial furrow, sometimes exhibiting eye ridge directed backward and outward from axial furrow on to palpebral lobe. Sharp genal angle, not prolonged into spine; posterior part of fixed cheek with short posterior border furrow just inside margin, dying out towards intersection with posterior branch of facial suture and also inwards. Rostral plate, hypostome, and thorax as in *Kosovopeltis* Šnajdr. Pygidium semi-elliptical, having very short, gently elevated, subtriangular axis with up to four pairs of poorly defined oval muscle impressions set well inside shallow axial furrows. Seven pairs of depressed, lateral pleurae, and usually unpaired, median pleura; pleural furrows weak, tend to die out near axial furrow and toward border. Pygidial doublure widest posteriorly, extending inwards to about one-half total length (sag.) of pygidium, but occasionally slightly more, almost to posterior tip of axis; doublure narrows anteriorly, with inner margin evenly curved and directed towards fulcra on anterior margin.

Discussion. Heptabronteus bears the closest resemblance to the Silurian genera *Kosovopeltis* and *Planiscutellum* R. and E. Richter, regarded by Šnajdr (1960) as belonging to the group of 'primitive' scutelluids. It most closely compares with *Kosovopeltis* (type species, *K. svobodai* Šnajdr, from the Upper Silurian of Bohemia), having a very similar glabella, including the arrangement of lateral glabellar muscle impressions, a similar, large eye placed posteriorly, rostral plate, hypostome, and thoracic segments. It differs principally in not having the genal angle prolonged into a spine, exhibiting a relatively longer pygidial doublure, covering virtually the entire postrhachial area (only 0·42 to 0·6 of this area is occupied by the doublure of the type species of *Kosovopeltis*; see Campbell 1967, p. 12), and in having a less inflated and trilobed pygidial axis. Several pairs of muscle scars may show on the axis, but not the two well-defined longitudinal furrows seen on the axis of *Kosovopeltis*. Also, larger specimens of *Heptabronteus* (notably in *H. major* sp. nov.) have a wider antero-lateral area of the fixed cheek, between axial furrow and anterior branch of the facial suture, and may exhibit a weakly developed eye ridge extending diagonally back into the palpebral lobe.

Compared to *Planiscutellum* (type species, *Bronteus planus* Hawle and Corda, from the Middle Silurian of Bohemia; see Šnajdr 1960), *Heptabronteus* has larger eyes and a rostral plate tapering more gently distally; it lacks a flattened, differentiated preglabellar area and axial rings on the pygidium, though pairs of muscle scars, possibly each pair confined to one segment, are seen. The pygidial doublure occupies a much greater part of the pleural regions posteriorly. Šnajdr's (1960, p. 233) claim that the pygidial doublure became enlarged in the course of phylogenesis in scutelluids, from the older, 'primitive', to the Devonian genera cannot be upheld. The earliest, 'Caradoc' representative of the older genera, *Heptabronteus atavus* sp. nov., has a doublure almost covering the entire postrhachial area, a condition not notably different from that found in the 'advanced' Devonian forms.

None of the other Ordovician scutelluid genera exhibits seven pairs of pleurae on the pygidium. *Eobronteus* Reed (type species, *Entomostracites laticauda* Wahlenburg, from the Boda Limestone of Dalarna, Sweden), differs in having a broad preglabellar area, a small, rounded lateral glabellar impression *1p*, a diagonal furrow running backward and outward from the axial furrow across the anterior part of the fixed cheek, opposite the lateral glabellar impression *1p*, another furrow curving backward and outward from the lateral muscle impression on the posterior part of the fixed cheek, broad-based genal spines, and six pairs of pleurae on the pygidium (Warburg 1925; Sinclair 1949; Šnajdr 1960). Also, the hypostome seems to have a more rounded posterior outline, and less conspicuous flaring outward and upward anterior wings. *Protobronteus* Šnajdr, 1960 closely resembles *Eobronteus*, but lacks a preglabellar furrow delimiting a broad preglabellar area. It is restricted to one, incompletely known, species, *P. reedi* (Sinclair), from the Middle Trenton of Quebec, and should perhaps be regarded as a junior synonym of *Eobronteus*. A broadening of the generic conception of this latter genus to include forms without a differentiated preglabellar area would seem preferable to retention of a genus based on such a small difference. *Octobronteus* Weber (type species, *O. khodalevitchi* Weber, from the Upper Silurian of the Urals) has even less resemblance to *Heptabronteus*. It exhibits a pygidium with eight pairs of pleurae, pleural furrows which slightly widen and deepen distally to immediately inside smooth border of variable width, and an axis which may be vaguely trilobed or shows segmentation. On the glabella there are conspicuous exsagittally elongated, anteriorly-narrowing, fused impressions of lateral glabellar furrows *2p* and *3p*, a tiny median node at the rear edge of the occipital ring, and prominent curved eye ridges running on to the palpebral lobes of the cheeks (Šnajdr 1960).

Heptabronteus could have been derived from *Eobronteus* since the latter appears somewhat earlier, in the Chazyan of eastern North America (Shaw 1968), but it seems more likely that both developed from a common ancestor among early Middle Ordovician styginids like *Bronteopsis* (Whittington 1950; Skjeseth 1955; Whittington *in* Moore 1959, pp. 365–367).

It seems probable that *Heptabronteus*, which is represented by two stratigraphically distinct 'Caradoc' species, *H. atavus* and *H. major*, in New South Wales, and by *Bronteus romanovskii* Weber in the Caradoc and Lower Ashgill of Kazakhstan (Tschugaeva 1958), is the forerunner of the conservative, rather unspecialized Silurian stock with seven pairs of pygidial pleurae, chiefly the genera *Planiscutellum* and *Kosovopeltis*. The Silurian forms evolved from the *Heptabronteus* stock occupying the restricted Kazakhstan–Australian region (*Heptabronteus–Pliomerina* province) during the Caradoc and Ashgill, and seem to have spread out to achieve a moderately cosmopolitan distribution by Middle and Upper Silurian times (Šnajdr 1960; Campbell 1967). From these arose a considerable number of specialized, relatively short-lived, endemic genera in the Lower Devonian, particularly in Bohemia (Šnajdr 1960).

Heptabronteus atavus sp. nov.

Plate 28, figs. 1–18

Material. Holotype (SUP 29908) and twenty-four paratypes (SUP 18903, 18906, 28900, 28931–28936, 28938, 28942, 28949, 29902–29903, 29905–29907, 29909a, 29911–29915, 29943) from the 'lower coral' unit on Fossil Hill, lower part of the Cliefden Caves Limestone. Also, one paratype (SUP 29901) from the 'mixed fauna' unit east of Fossil Hill, lower part of the Cliefden Caves Limestone.

Description. Cranidium gently convex transversely and longitudinally, becoming more strongly convex at anterior margin, with slight overhang of margin. No trace of preglabellar furrow separating frontal region of cranidium. Glabella narrowest opposite lateral muscle impressions on fixed cheeks, expanding forwards to become widest anteriorly, in front of lateral glabellar impressions *1p*; widens posteriorly across occipital ring to posterior margin. Axial furrow deeply impressed throughout most of its course but appears to die out before reaching antero-lateral margin. Very weak sag (rather than furrow) extends diagonally backward and outward from anterior end of axial furrow towards anterior branch of facial suture. Occipital furrow deep, prominent; deflected forwards and less deeply impressed medially; deep, slot-like lateral occipital ?muscle impressions in furrow laterally. Occipital ring, gently convex transversely; slopes gently forward into occipital furrow, and is more steeply inclined backward. Very gentle backward arch of posterior margin. Glabella exhibits three pairs of faint, lateral glabellar impressions (Pl. 28, fig. 1). Lateral glabellar impression *1p* is an elongated, slot-like impression extending from just inside axial furrow inwards and forwards, parallel to antero-lateral margin. Oval-elongate lateral glabellar impression *2p* is situated further inside axial furrow, near mid-length of glabella (excluding occipital ring); *1p* is almost half-way between *2p* and antero-lateral margin; *3p* is placed on axial furrow, and is larger than lateral muscle impression on fixed cheek, but much less well defined; placed so that posterior edge of *3p* is directly opposite anterior edge of lateral muscle impression. Large, oval lateral muscle impression deeply imprinted on fixed cheek; situated a little way in front of occipital furrow. Terrace lines subparallel to margin in anterior part of cranidium. Fixed cheek flattened transversely towards palpebral lobe; sloping gently backwards, and more steeply forwards towards antero-lateral corner. Palpebral lobe crescent-shaped, slightly raised. Anterior branch of facial suture directed forward and outward almost parallel with axial furrow, but some distance away from it, and continues to antero-lateral margin, where it turns sharply inwards and downwards to continue course between doublure and rostral plate. Behind palpebral lobe, posterior branch of the suture curves sharply downward and outward on to the posterior margin well inside genal angle. No trace of eye ridges seen. Width across one fixed cheek at level of palpebral lobe just less than least width across glabella measured between lateral muscle impressions.

Free cheek with large, posteriorly placed, raised, crescent-shaped eye lobe, and broad, flattened, outer surface, or platform. Convex visual surface extends around lobe from forward (and slightly inward) to outward and backward. Overall alignment of eye seems to be slightly oblique, more or less parallel to antero-lateral margin of free cheek. There may be slight forward tilt of visual surface, giving highest elevation of lobe to the rear. Antero-lateral margin of free cheek has coarse raised lines running along it, gradually becoming finer towards genal angle (Pl. 28, fig. 6). Dorsal surface of flattened outer part of free cheek covered by wavy, anastomosing, rather wide-spaced lines, in the anterior half deflected backwards and outwards, and in the posterior half more typically arranged transversely with backward deflection marginally. Surface between lines covered with tiny pits. Sharp discordance between coarse, continuous, raised lines on antero-lateral margin and fine, wavy transverse-diagonal lines of outer part of free cheek. Genal angle sharply pointed but not prolonged. Posterior margin wide, almost straight; no trace of posterior border furrow. Doublure occupies much of the undersurface of free cheek, with broadly spaced terrace lines similar to those on rostral plate, approximately parallel with lateral margin, except for inward deflection of lines towards posterior margin

EXPLANATION OF PLATE 28

Figs. 1–18. *Heptabronteus atavus* sp. nov., from the lower part of the Cliefden Caves Limestone. 1–15, 17–18 from 'lower coral' unit, Fossil Hill; 16, from 'mixed fauna' unit east of Fossil Hill. 1, dorsal view of latex impression of cranidium; holotype SUP 29908, ×8. 2, dorsal view of incomplete cranidium of paratype SUP 28931, ×4. 3, dorsal view of fragmentary cranidium of paratype SUP 18903, ×3. 4–5, anterior and dorsal views of incomplete cranidium of paratype SUP 29907, ×4. 6, dorsal view of latex impression of left free cheek, SUP 29909a, ×5. 7, dorsal view of small left free cheek, paratype SUP 29914, ×6. 8, oblique lateral view of latex cast of exfoliated right free cheek, paratype SUP 29912, ×4. 9, oblique dorso-lateral view of right free cheek of paratype SUP 28942, ×4. 10, ventral view of incomplete rostral plate, paratype SUP 29902, ×5. 11, ventral view of latex cast of part of rostral plate, paratype SUP 18906, ×4. 12, ventral view of latex impression of hypostome, paratype SUP 28935, ×6. 13, oblique ventral view of latex cast of fragmentary hypostome, paratype SUP 28936, ×5. 14, dorsal view of incomplete thoracic segment, paratype SUP 28938, ×4. 15, dorsal view of exfoliated pygidium showing extent of doublure, paratype SUP 28949, ×3. 16, dorsal view of pygidium, paratype SUP 29901, ×3. 17, dorsal view of latex cast of partly exfoliated pygidium, SUP 28900, ×4·5. 18, ventral view of incomplete pygidium showing part of broad, gently concave doublure, paratype SUP 29905, ×3.

Figs. 19–20. *Heptabronteus major* sp. nov., from the Malongulli Formation. 19, dorsal view of latex cast of thoracic segments from near Mirrabooka homestead, Cheeseman's Creek area, paratype SUP 20914, ×4. 20, dorsal view of compressed pygidium from Trilobite Hill, paratype SUP 19934, ×1·5.

WEBBY, *Heptabronteus*

where doublure widens behind eye. Anteriorly, doublure has convex rolled appearance, but becomes progressively more flattened posteriorly.

Rostral plate large, very broad, gently convex (sag. and exsag.) defined by inwardly and backwardly directed connective sutures; gently curved anterior and posterior margins giving most expanded portion medially; in addition to backward curvature of posterior margin, it is also gently arched downwards medially. Anterior branches of facial suture turn sharply inward at antero-lateral margin into long, gently curved, horizontal rostral suture bounding anterior margin of rostral plate. Terrace lines prominent, and on outer (ventral) surface arranged parallel to posterior and anterior margins.

Hypostome with shield-shaped outline, posterior border wider (sag. and exsag.) than lateral border; posterior and lateral margins almost straight, with sharp postero-lateral angle between them; slightly projecting shoulder. Gently convex middle body divided broadly by diagonal, middle furrows into larger, anterior, and smaller, posterior crescent-shaped parts. Smooth-surfaced, crescentic macula occupies area adjacent to middle furrow; area between macula and lateral border furrow has terrace lines in continuity with those of posterior part of middle body. Faint suggestion of tubercle occasionally seen on raised postero-median edge of macula. Posterior border furrow runs in gentle curve in continuity with lateral border furrow. Faint pit in furrow at postero-lateral corner on each side. Lateral border furrows continue to diverge anteriorly, finally dying out in triangular base of anterior wing. Anterior margin curves gently downwards and backwards medially. Anterior wings large, triangular, directed upward and outward. Coarse terrace lines, similar to those on rostral plate, extend across hypostome; curve down off anterior wings, across middle body with convexity to the rear, and parallel to lateral and posterior borders.

Only one fragmentary thoracic segment seen (Pl. 28, fig. 14). Axis gently convex, both transversely and longitudinally, becoming moderately steep (about 55° to horizontal) near axial furrow. Terrace lines concentric about postero-median part of axis. Pleura consists of relatively short, horizontal, transverse, gently convex (exsag.) inner, and gently inclined (at about 40° to horizontal), slightly longer (tr.) outer parts. Terrace lines inclined diagonally forward and slightly outward on inner part, more obliquely outward on outer part except for distal extremity where lines become subparallel to outer margin of thorax.

Pygidium semi-elliptical, gently convex, with evenly rounded lateral and posterior margins, and moderately sharply rounded antero-lateral corners; almost straight, transverse anterior margin except for tongue-like forward extension of gently convex articulating half ring. Axis subtriangular, occupying about one-third of total length (sag.) of pygidium, and about one-third of width at anterior margin. No segmentation seen on axis behind anterior articulating furrow. Axial furrows very slightly impressed. Pleural regions broad, gently convex, with seven pairs of weakly developed pleurae and median undivided pleura. Weakly imprinted pleural furrows which tend to fade out near axial furrow and also toward margins. Width of median undivided pleura near margin usually similar to width of adjacent paired pleurae. Terrace lines more or less transverse across entire dorsal surface of pygidium, with slight forward curvature near lateral margins. Doublure occupies about two-thirds of the total sagittal length of pygidium, virtually entire area of pleural regions behind axis, but narrows approaching anterior margin, with inner edge of doublure meeting margin at fulcrum (Pl. 28, fig. 15); medially, inner edge of doublure curved evenly behind axis.

Remarks. Bronteus romanovskii Weber from the Caradoc to Lower Ashgill of Kazakhstan (Tschugaeva 1958) bears very close similarities to *Heptabronteus atavus*, and is undoubtedly congeneric. The only significant differences between the two species seem to be suggested by the course of the facial suture. From the outline of the suture around the palpebral lobe, it seems likely that *H. romanovskii* had a slightly smaller eye (Weber 1948, text-fig. 16). Secondly, though better depicted in Tschugaeva's (1958) material, the anterior branch of the suture in *H. romanovskii* seems to be much less parallel to the axial furrow than in *H. atavus*, or more exsagittally than diagonally (forwardly and outwardly) directed.

Heptabronteus major sp. nov.

Plate 28, figs. 19–20; Plate 29, figs. 1–6

Material. Holotype (SUP 20903) and three paratypes (SUP 18904, 20912a, 20913) from the Malongulli Formation at Copper Mine Creek, and two paratypes (SUP 19934, 19936) from the same horizon at Trilobite Hill. Also two paratypes (SUP 20914, 26935) from the Malongulli Formation near Mirrabooka homestead, north of Cheeseman's Creek.

Comparative description. This larger species of *Heptabronteus* has a flattened cranidium, with evenly rounded anterior margin and relatively wide fixed cheeks. Axial furrow is less deeply impressed throughout its course except at level of lateral muscle impression on fixed cheek. Lateral glabellar furrows only faintly impressed, *1p* and *2p* transversely elongate-oval, set inside axial furrow; *2p* slightly larger than *1p*, and placed just behind mid-length of glabella (excluding occipital ring); *1p* almost midway between *2p* and anterior margin of cranidium; large *3p* impression on side of axial furrow very ill-defined, about midway between *2p* and occipital furrow. Occipital furrow sharp and deeply impressed medially, but widens (exsag.) and shallows laterally into attachment area with subtriangular ?muscle scars. Lateral muscle impressions on fixed cheeks only faintly shown. Fixed cheek relatively broad, about equal or slightly wider at level of palpebral lobes to width across narrower, posterior part of glabella; much wider across fixed cheek in front of palpebral lobe than in *H. atavus*. Weakly impressed eye ridge runs diagonally backward and outward from axial furrow just in front of lateral glabellar impression *2p* on to palpebral lobe (Pl. 29, fig. 1). Posterior branch of facial suture curves outward and then backward (and slightly inward) around small posterior projection at distal end of fixed cheek adjacent to posterior margin; short discontinuous posterior border furrow developed just inside margin only near distal end of fixed cheek (Pl. 29, fig. 4). Surface of cranidium covered by fine slightly anastomosing terrace lines, transversely arranged near anterior margin and on glabella, but deflected backward at axial furrow; on posterior part of glabella just in front of occipital furrow and on occipital ring form concentrically arranged, convex forward arcs; on fixed cheeks, somewhat anastomosing terrace lines form concentric arcs centred on palpebral lobe, running in increasingly large arcs forward and inward.

Hypostome, though somewhat crushed, exhibits relatively larger anterior lobe of middle body, and rather inconspicuous macula situated adjacent to inner part of middle furrow; lateral border furrow deep, becoming shallower postero-laterally, and defining narrow, raised lateral border and its continuation, long (sag.), gently convex posterior border; postero-lateral margin more rounded than in *H. atavus*. External surface covered by fine, concentrically arranged lines, much finer than in *H. atavus*.

Only four thoracic segments seen in articulation. Axis relatively narrow, gently convex, estimated to occupy between one-quarter and two-sevenths of total thoracic width; axial furrows distinctly impressed and have slight zigzag outline between articulated segments. Articulating furrows broad, well-defined, slightly obliquely inclined to posterior margin, giving axial ring slight hour-glass outline. Pleurae gently convex (exsag.), almost flat (tr.), parallel-sided from axial furrow to fulcrum, with horizontal hinge line; beyond fulcrum a barely discernible expansion, and then tapers distally to backwardly turned, pointed pleural tip. Anterior and posterior margins of pleurae with moderately sharp edges; transverse lines may show on posterior edge of outer part of pleura. Terrace lines arranged concentrically out from centre near middle-rear of each axial ring, though there may be additional more or less transverse lines along rear edge of axial ring; also transverse lines on articulating half ring. Terrace lines directed forward and outward on inner part of pleura, but beyond fulcrum, become longitudinally directed and on tapering pleural tips may be slightly inwardly and forwardly inclined.

Pygidium relatively longer, narrower and flattened (probably in part by compression), with well-rounded antero-lateral corners. Relatively small, subtriangular axis bounded by weak axial furrows; occupies between one-quarter and two-sevenths of total sagittal length of pygidium, and between one-fifth and one-quarter of maximum pygidial width; tongue-like forward extension of gently convex articulating half ring, crossed by ornamentation of fine lines; articulating furrow broad, moderately deep, and smooth. Four (or ?five) pairs of elongate to oval muscle scars developed on axis behind articulating furrow. Seven lateral pairs of pleurae and broader, unpaired, median pleura; pleurae flattened to gently convex, intersected by moderately deep, narrow pleural furrows which weaken toward axial furrow and approaching margin. Doublure extends from fulcrum outward to lateral margins, but posteriorly increases in width to cover large part of pleural regions extending to more than one-third of total length of pygidium; in small specimen (Pl. 29, fig. 5) extends one-half total pygidial length; prominent, wide-spaced terrace lines more or less parallel to posterior and lateral margins.

To summarize, this larger species of *Heptabronteus*, *H. major*, may be distinguished from the type species, *H. atavus*, by having a cranidium with an eye ridge crossing the fixed cheek diagonally on to the palpebral lobe, a relatively wider area of the fixed cheek in front of the eye ridge, a less conspicuous lateral muscle impression, less prominent axial furrows anteriorly, less deeply indented lateral ends to the occipital furrow, a hypostome with a larger, rounded anterior lobe of the middle body, less conspicuous maculae, a more rounded postero-lateral margin, and finer terrace lines on the external surface, and a relatively longer and narrower pygidium with the axis occupying a smaller proportion of the entire area of the pygidium, pairs of muscle scars on the axis, more rounded antero-lateral corners, and a relatively wider, unpaired, median pleura.

Family DIMEROPYGIDAE Hupé, 1953
Genus TOERNQUISTIA Reed, 1896*a*

Type species. Cyphaspis (*Toernquistia*) *nicholsoni* Reed

Toernquistia arguta sp. nov.

Plate 29, figs. 7–9

Material. Holotype (SUP 26931) and two paratypes (SUP 26930, 26932) from the Malongulli Formation near Mirrabooka homestead, 2 miles north of Cheeseman's Creek Post Office.

Description. Glabella narrowing forward, rounded anteriorly, convex; outlined by deep, continuous axial and preglabellar furrows; maximum height near mid-point. Pair of weakly impressed lateral glabellar furrows *1p* extend obliquely inwards and backwards at about 45° to exsagittal line, to isolate small, subtriangular lateral glabellar lobes *1p* in postero-lateral corners of glabella (Pl. 29, fig. 9). Glabella estimated to be slightly more than one-half total length of cephalon, and to have width across posterior part somewhat less than one-third total width of cephalon. Glabella measures from 0·5 to 1·1 mm wide and 0·6 to 1·2 mm long (sag.). Deep, broad occipital furrow with very slight forward convexity. Occipital ring convex, very short, with lenticular dorsal outline; posterior margin convex backwards. Surface of occipital ring not well enough preserved to confirm presence or absence of median tubercle; deeply impressed pits on axial furrow opposite lateral ends of occipital ring, represent large axial sockets for articulation of first thoracic segment.

Preglabellar field moderately convex, sloping forward and downward to anterior furrow, and more steeply backward into preglabellar furrow; bounded by diagonal furrows which extend outward and slightly forward, weakening distally and curving forward to merge with anterior branches of facial suture (Pl. 29, fig. 8). Deep median pit in preglabellar furrow has sagittally aligned, slot-like depression extending forward from it almost halfway across preglabellar field. Anterior border gently convex, rim-like, separated from preglabellar field by rather shallow anterior furrow. Fixed cheeks convex, moderately broad, more or less L-shaped, slightly less elevated than glabella, and separated by diagonal furrow from preglabellar field, and by deep posterior furrow from posterior border; palpebral lobe narrow, raised, but incompletely preserved. Small granules cover dorsal surface of glabella, preglabellar field, and fixed cheeks.

Remarks. T. arguta may be distinguished from all the known species of *Toernquistia* recorded from the Caradoc and Ashgill of Britain and Sweden (Warburg 1925; Thorslund 1940; Whittington 1950; Dean 1962). *T. nicholsoni* Reed, the type species, from the Keisley Limestone (Ashgill) of the Cross Fell Inlier, northern England, exhibits close resemblances, but the occipital ring is longer (sag.), proportions across the glabella and fixed cheeks are different, with the fixed cheeks relatively narrower, lateral glabellar lobes *1p* are not shown to be differentiated, and a coarser granulation is developed on the dorsal surface (Whittington 1950). On the other hand, a pair of small, subtriangular lateral glabellar lobes *1p* are reported by Warburg (1925) on Swedish specimens of *T. nicholsoni* from the Boda Limestone of Ashgill age. *T. reedi* Thorslund, 1940 from the Lower Chasmops Limestone (4bβ) of Jemtland, Sweden, also has much narrower fixed cheeks, but similarly shows lateral glabellar lobes *1p*. *T. translata* (Reed) from the Balclatchie Group (Lower–Middle Caradoc) of Girvan, Scotland (Reed 1904, 1931) is in need of revision. It apparently has a less well-defined median, slot-like depression on the preglabellar field, a relatively shorter (sag.), less anteriorly tapering glabella, and slightly larger lateral glabellar lobes *1p*. The diagonal, antero-lateral furrows in *T. depressa* Warburg from the Boda Limestone of Dalarna, Sweden, are only represented as very faint traces (Warburg 1925).

Another species of *Toernquistia*, *T. shlygini* Weber, is recorded from the Upper Ordovician of Kazakhstan. However, it has a much longer (sag.) occipital ring, relatively narrower fixed cheeks, and a longer (exsag.) posterior border (Weber 1948). *Toernquistia*? *idahoensis* Churkin from the late Middle–Upper Ordovician of Nevada and Idaho may be distinguished by the longer (sag.) preglabellar field and less conspicuous slot-like preglabellar depression.

Family TRINUCLEIDAE Hawle and Corda, 1847
Genus PARKESOLITHUS Campbell and Durham, 1970

Type species. *P. gradyi* Campbell and Durham, 1970.

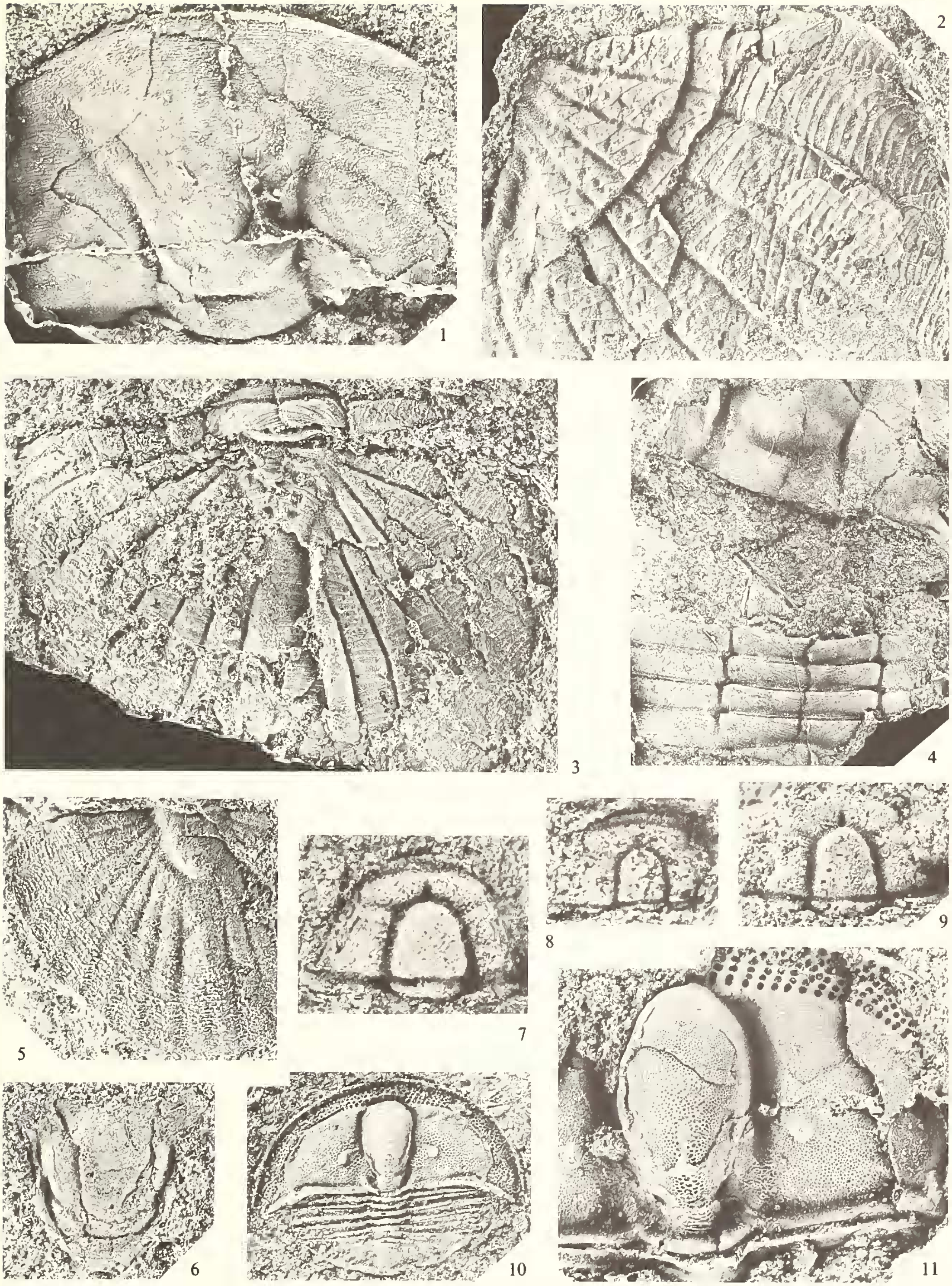
Diagnosis. Trinucleid genus with eye tubercles in adult; glabella with furrow *1p* represented by large, elongate-triangular depressed area containing deeper postero-lateral and antero-median pits, and virtually imperceptible furrows *2p* and *3p*; occipital spine absent; fringe of two E arcs and from two to five continuous I arcs, with possible addition of further two I arcs laterally; auxiliary pits may occur in E_2, occasionally suggesting discontinuous E_3 arc laterally. Greatest regularity of pitting in antero-median parts of inner, I arcs, and usually extends about two-thirds of total distance around inner edge of fringe from mid-line to posterior border; outer I arcs, I_1 and I_2 may have irregular pitting, even antero-medially; addition of new

EXPLANATION OF PLATE 29

Figs. 1–6. *Heptabronteus major* sp. nov., from the Malongulli Formation. 1, 4–6, from Copper Mine Creek; 3, from Trilobite Hill; 2, 7, from near Mirrabooka homestead, north of Cheeseman's Creek. 1, dorsal view of latex impression of cranidium, holotype SUP 20903, ×3. 2, dorsal view of latex cast of part of exfoliated pygidium, paratype SUP 26935, ×3. Note two sets of terrace lines, one on dorsal surface, and the other, laterally, on doublure. 3, dorsal view of latex impression of pygidium, paratype SUP 19936, ×2. 4, dorsal view of latex impression of part of cranidium and four isolated thoracic segments (reversed orientation), paratype SUP 20912a, ×2·5. Note also small, left free cheek of *Remopleurides exallos* Webby. 5, dorsal view of part of small pygidium, paratype SUP 20913, ×4. 6, ventral view of compressed, rather poorly preserved hypostome, paratype SUP 18904, ×3.

Figs. 7–9. *Toernquistia arguta* sp. nov., from the Malongulli Formation near Mirrabooka homestead, north of Cheeseman's Creek. 7, dorsal view of internal cast of cranidium, paratype SUP 26930, ×10. 8, dorsal view of internal mould of small cranidium, paratype SUP 26932, ×15. 9, dorsal view of internal cast of cranidium, holotype SUP 26931, ×10.

Figs. 10–11. *Parkesolithus dictyotos* sp. nov., from the Malongulli Formation. 10, dorsal view of latex impression of external mould of small specimen from near Mirrabooka homestead, north of Cheeseman's Creek, paratype SUP 26905, ×6. 11, dorsal view of latex cast of external mould of part of holotype, SUP 26920, ×5, from Copper Mine Creek.



WEBBY, *Heptabronteus*, *Toernquistia*, *Parkesolithus*

I arcs on external side of innermost I_n arc. E_1 and E_2 separated by sharp ridge on upper lamella; weak girder on lower lamella of equal development to E_{1-2} pseudogirder. Thorax of six segments. Pygidium subtriangular, broader than long, with eight or more weak axial rings, weakly furrowed to smooth pleural field, and prominent, raised posterior border.

Discussion. The generic diagnosis proposed by Campbell and Durham (1970) has been widened to accommodate *P. dictyotos* sp. nov., a species exhibiting ornamentation on the glabella, cheeks, and thorax, additional I arcs, up to five of which are continuous and usually a further two developing laterally, greater irregularity of pitting in I_1, and I_2, and sometimes I_3 arcs, numerous additional pits in E_2 occasionally creating the impression of a third row, and fewer, usually five, faint pleural ribs on the pygidium.

Campbell and Durham (1970), referring to the nature of the pit arrangement on the fringe of *P. gradyi*, noted the continuity of I_4 and interruption of I_3 in front of the glabella. A similar pattern is seen in *P. dictyotos*, though interruption of I arcs is not confined to the area in front of the glabella. The innermost I arc appears to be continuous around the inner margin of the fringe, and new, incomplete I arcs (usually I_4 and I_5) are added on its external side between the mid-line and posterior border. The slightly modified notation proposed by Ingham (1970) for use in describing the *Tretaspis* fringe may also be applied to *Parkesolithus*. The new I arcs are apparently inserted on the external side of the innermost arc, supposedly the parent arc. The innermost arc is left unnumbered and given the symbol I_n, thus solving the problem of its changing I number around the inner margin. But the overall variability in the arrangement of pitting on the fringe of *Parkesolithus* individuals leaves considerable doubt as to whether the conventional fringe formula is the most satisfactory method of representation. Perhaps construction of fringe maps for each individual would provide a more satisfactory means of comparison of these forms.

In addition to possible relationships with *Cryptolithus* Green and *Broeggerolithus* Bancroft, discussed by Campbell and Durham (1970), *Parkesolithus* may be allied to *Lloydolithus* Bancroft. The type species, *L. lloydi* (Murchison), from the Llandeilo Series of Wales and the Welsh Borderland (Whittard 1958) has some similarities, showing two E arcs, with variable numbers of auxiliary pits creating the impression of three E arcs in a few radii, complete I_{1-5} arcs with sometimes an incomplete I_6 arc, and auxiliary pits appearing in I_1, I_2, and on the I_{1-2} and I_{2-3} pseudogirders. But the prominent eye ridges in younger forms of *L. lloydi* become reduced to 'nodules' adjacent to the curved axial furrows in the adult, whereas the eye tubercles of adult forms of *Parkesolithus* are well developed. Furthermore, *L. lloydi* differs from *Parkesolithus* in lacking a clearly differentiated occiput and a sharp E_{1-2} ridge on the upper lamella, in having a narrow preglabellar field, an occipital spine, an overall greater regularity of pitting on the fringe, especially in I_1 and I_2, a more prominent girder on the lower lamella, a less-pointed genal prolongation, and a greater number of stronger pleural ribs and axial rings on the pygidium.

Parkesolithus dictyotos sp. nov.

Plate 29, figs. 10–11; Plate 30, figs. 1–11; Plate 31, figs. 1–3

Material. Holotype (SUP 26920) and sixteen paratypes (SUP 26914a–b, 26915a–b, 26917–26919, 26921a–b, 26922–26927, 26929) from the Malongulli Formation at Copper Mine Creek, and six paratypes (SUP 6910, 7914–7917, 13907) from the same horizon at Trilobite Hill, near Mandurama. Fifteen additional paratypes (SUP 26903, 26904a–c, 26905, 26906a–d, 26907–26909, 26911–26913) from the Malongulli Formation near Mirrabooka homestead, north of Cheeseman's Creek Post Office.

Description. Cephalon semicircular, twice to slightly more than twice as wide as long (sag.); somewhat crushed and flattened in specimens examined; about equal to length (sag.) of thorax and pygidium combined. Glabella pyriform, elevated above adjacent cheeks; apparently reaches maximum height near mid-length (sag.); outlined by broad, deep, gently curving axial furrows, which become very shallow to rear. Two small anterior pits mark sites of anterior fossulae, each at anterior end of axial furrow and separated by low ridge from fringe (Pl. 30, fig. 1). No median tubercle. Glabella protrudes slightly in front of adjacent cheeks displacing and constricting inner arcs of fringe. Lateral glabellar furrow *1p* consists of large, elongate to triangular depression containing a deeper, oval, postero-lateral pit inside axial furrow, just in front of apodemal pit in occipital furrow, and a sharp notch in the lateral slope of glabella antero-medially; marks rear of anterior glabellar lobe. Furrows *2p* and *3p* extremely faintly impressed on slopes of glabella inside axial furrow; *2p* developed as a large, very weakly imprinted, oval-shaped area in front of *1p* (Pl. 30, fig. 5), and *3p*, as a small, faint indent situated about glabellar mid-length (sag.). Anterior glabellar lobe moderately elongate and swollen, occupies about five-sixths of length of glabella; occiput not very swollen, about one-half width of anterior glabellar lobe. Occipital ring short, convex, with sharp-ridged posterior margin, arching backwards sagittally; low, narrow ridges extend along inside margins of axial furrows from lateral ends of occipital ring, and die out opposite anterior edges of furrows *1p*. Occipital furrow deepens laterally into oval apodemal pits, set inside axial furrows, and only separated from deep, postero-lateral pits of furrows *1p* by low ridge.

Cheeks broad, quadrant-shaped, gently convex, with steeper outer slopes; sometimes exhibiting gently raised rim along antero-lateral margin adjacent to fringe. Prominent, rounded eye tubercles situated just behind glabellar mid-length, and out from axial furrow; in small specimens, curved, tapering elongation of eye tubercle to form incipient eye ridge running forward and inward toward axial furrow opposite furrow *3p* (Pl. 29, fig. 10). Faint, fine genal caecae may be seen branching outward across cheek from vicinity of eye tubercle; more prominent, undivided caeca extends postero-laterally from eye tubercle towards lateral pit (Pl. 29, fig. 11). Raised posterior border slopes gently forwards and, from its sharply rounded crest, steeply backwards; transverse and horizontal inner course, but deflected downward and slightly backward laterally. Posterior border furrow also transverse and horizontal, extending from axial furrow to inner corner of widest part of fringe. Large lateral pit placed towards outer end of furrow, but separated from smaller pits of fringe.

Glabella and cheeks have surface ornamentation of fine pits, becoming coarser and forming a more reticulate pattern posteriorly, towards posterior border furrow on cheek, and along median part of glabella behind furrow *3p*; occiput has coarse reticulation which becomes more or less transversely aligned near occipital furrow.

Inner part of upper lamella of fringe slopes gently downward; outer part sharply reflected in prominent E_{1-2} ridge. Fringe fairly constant in width, though narrowing slightly in front of glabella, widening across genal flange and tapering rapidly towards genal angle. Strong E_{1-2} ridge persists around anterior and lateral margin but weakens and disappears approaching genal angle (Pl. 30, fig. 11). Usually 7–8 arcs of pits developed, E_{1-2} and I_{1-4+n} or I_{1-5+n}. Occasionally an additional arc, I_6, appears on external side of I_n arc in lateral areas (Pl. 30, fig. 9). Outer I arcs, especially I_{1-2}, rather haphazardly arranged, but inner arcs (I_{3-6}) in anterior areas, moderately well ordered; postero-laterally, progressively more I arcs, from outside inwards, assume irregular arrangement of pitting, completely losing their ordered radial arrangement from opposite widest part of cephalon excluding fringe to genal angle. External arcs usually have slightly larger and more widely spaced pits. Considerable numbers of auxiliary pits may occur in E_2, especially laterally, giving impression in some radii of discontinuous E_3 arc. Occasional auxiliary pits may also appear on E_{1-2} ridge; rarely developed in E_1 except postero-laterally. Counts of from 21 to 34 ordered radial rows (with two or more radially aligned pits) in I arcs away from mid-line. Apparent continuity of innermost I_n arc. Usually two new, incomplete I arcs develop on external side of innermost arc, the first to the side of forward protrusion of glabella, the second further out along inner margin of fringe. Twin pits frequently formed at bifurcation of these inner arcs.

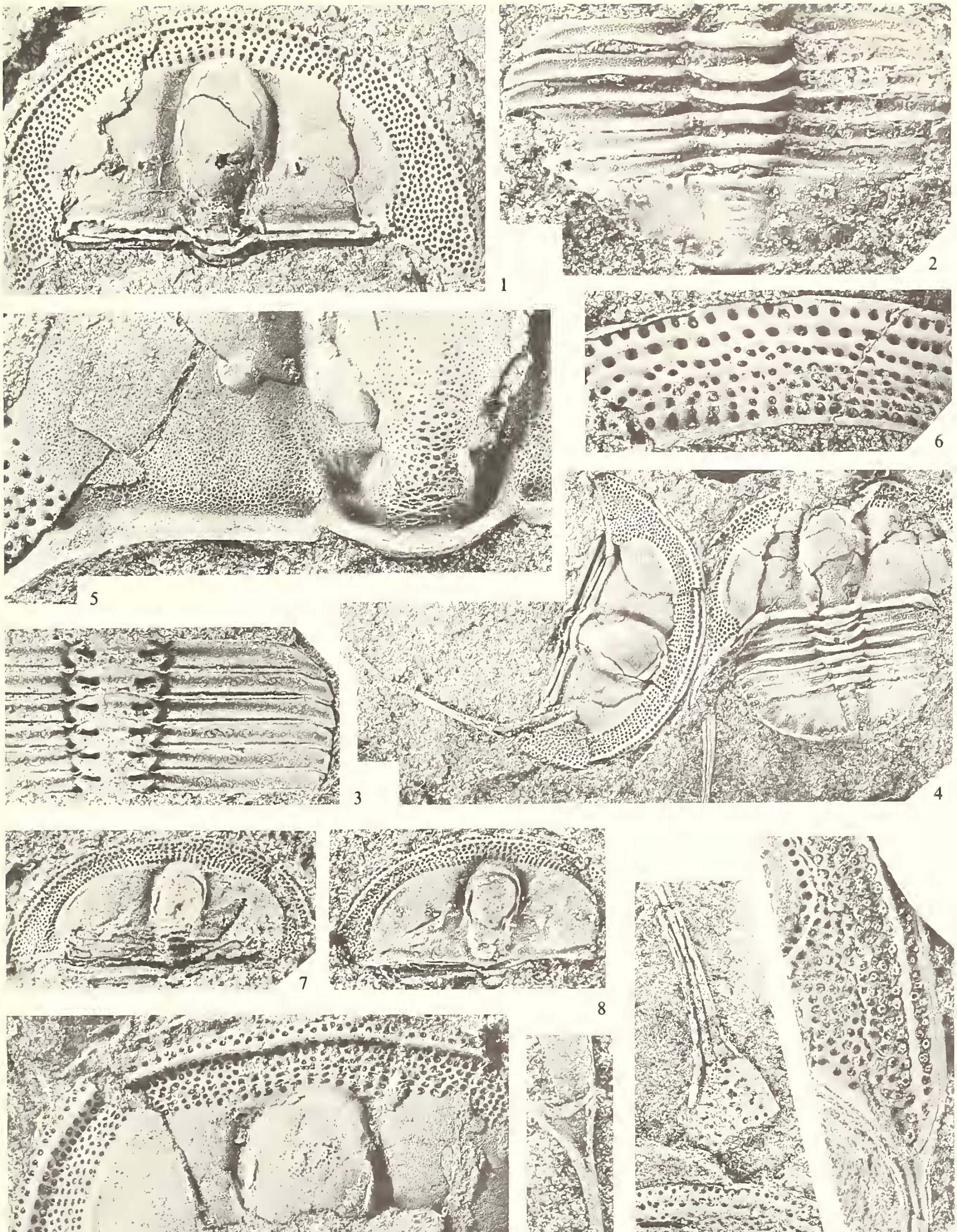
On lower lamella, girder weak, ridge-like structure, no more prominent than E_{1-2} pseudogirder; appears to die out before reaching posterior extremity (Pl. 31, figs. 2–3); most easily recognized by change in nature of pitting from larger, wider-spaced pits of E arcs to smaller, more closely spaced pits in I arcs. Terrace lines developed along rolled inner edge of lower lamella (Pl. 30, fig. 6). Prominent keel on ventral surface of genal spine tends to fade out at posterior corner of fringe and does not appear to continue into weakly developed girder or pseudogirders. Genal spine long, very

---

EXPLANATION OF PLATE 30

Figs. 1–11. *Parkesolithus dictyotos* sp. nov., from the Malongulli Formation. 1–4, 6, 10, from Copper Mine Creek; 9, from Trilobite Hill; 5, 7–8, 11, from near Mirrabooka homestead, north of Cheeseman's Creek. 1, dorsal view of internal mould of holotype, SUP 26920, ×3·5. 2, dorsal view of latex impression of external mould of thorax and pygidium, paratype SUP 26922, ×5. 3, dorsal view of internal mould of thorax of paratype SUP 26921a, ×4. 4, dorsal view of latex impression of two paratypes, an incomplete exoskeleton, SUP 26915a, and a cephalon, with long genal spine (left side), SUP 26915b, ×2. 5, enlarged dorsal view of latex cast of paratype, SUP 26904a, showing pattern of ornamentation on posterior part of cephalon, ×6. 6, ventral view of latex impression of lower lamella, paratype SUP 26925, ×5. 7–8, dorsal views of internal and external (latex) moulds of paratype SUP 26908, ×6. 9, dorsal view of latex impression of part of large cephalon, paratype SUP 7915, ×3. 10, ventral view of latex impression of portions of lower lamella and genal spine, paratype SUP 26919, ×3. 11, dorsal view of latex cast of upper lamella and part of genal spine, paratype SUP 26904b, ×4.

Fig. 12. *Malongullia oepiki* Webby, Moors, and McLean 1970 (dimorph A) from the Malongulli Formation near Mirrabooka homestead, north of Cheeseman's Creek. Ventral view of latex impression of part of left free cheek showing doublure and genal spine, SUP 27907, ×6.



WEBBY, *Parkesolithus*, *Malongullia*

gently curved, presumed to project rearwards about twice length of pygidium beyond posterior tip; sharp-ridged, quadrate cross-section, in apparent continuity with lower lamella. Facial suture runs along dorso-marginal edge of fringe, crosses genal angle dorsally, and isolates genal spine on lower lamella. Keel-like ridge on dorsal side of genal spine stops abruptly against suture on genal angle (Pl. 30, fig. 11). Hypostome not known.

Thorax of six segments, each of similar length (sag. and exsag.); usually about three times wider than long. Axis occupies about one-fifth total width, tapering very slightly towards pygidium, transversely convex and elevated above adjacent, flatter pleurae; defined by well-developed axial furrows, especially internally (Pl. 30, fig. 3). Axial rings relatively short (sag. and exsag.), the first four markedly sharp crested (sag.), and the last two more rounded (sag.); separated from articulating half ring by moderately deep articulating furrow which descends laterally into very deep, slot-like, transversely elongated apodemal pits set well inside axial furrows. Articulating half rings short, usually gently convex forwards, but on first segment almost transverse. Pleurae of third and fourth segments widest (tr.); pleurae of first segment taper laterally, with large facets developed on antero-lateral angles, set at angle of about 30° to transverse direction, enabling them to fit neatly in behind posterior cephalic border. Through progressive outward movement of fulcrum towards pygidium, succeeding pleurae have narrower facets and blunter, backwardly turned pleural tips. Ends of pleurae sharply downturned. Pleural furrows very broad (exsag.) and moderately deep; on pleurae of first and second segments commencing just in front of mid-length (exsag.) on axial furrow, but on remainder originate nearer anterior margin; directed towards distal extremity of each pleura, but not continuous across narrow marginal rim. Coarse reticulate pattern of ornamentation developed on median part of anterior-facing slopes of sharply crested axial rings on first, second, and third segments, and less prominently on fourth segment. Pleural furrows of first and second segments exhibit finer reticulation, and those of third and fourth segments have an even finer meshwork. Fifth and sixth segments appear to be smooth.

Pygidium subtriangular, approximately two-thirds length (sag.) of thorax; three to four times wider than long, with smaller specimens even relatively wider. Up to eight fused axial rings, each progressively shorter and narrower towards rear, and small terminal piece. Axial furrows broad, moderately well marked, curving inwards towards posterior margin, and separating raised axis from more or less flat pleural field. Anteriorly, pair of prominent, slot-like apodemal pits on either side of articulating furrow; articulating half ring, gently convex forwards (Pl. 31, fig. 1). Anterior margin excluding articulating half ring, straight; posterior margin usually rounded. Up to six pairs of weakly developed pleural ribs, but more usually five; directed progressively more strongly backward to rear; often pleural field almost flat and smooth, with only gentle flexures representing pleural ribs adjacent to postero-lateral border. Narrow, crested postero-lateral border widens (sag. and exsag.) towards mid-line, and exhibits faint, closely spaced terrace lines on steeply declined posterior flank of border. Dorsal surface of pygidium smooth.

Measured overall length of exoskeleton excluding prolongation of genal spines behind pygidium from 5 to 20·2 mm; width including fringe from 6·5 to 22·5 mm.

From large fragmentary specimens, estimated to reach maximum length of 26 mm and width of 31 mm.

Remarks. The type species of *Parkesolithus*, *P. gradyi*, from the unnamed Upper Ordovician shales west of Parkes differs from *P. dictyotos* in having few if any auxiliary pits in E_2, only two–three continuous I arcs, a relatively wider pygidium in larger specimens than in smaller, and an unornamented cephalon and thorax (Campbell and Durham 1970).

Family RAPHIOPHORIDAE Angelin, 1854
Genus MALONGULLIA Webby, Moors, and McLean, 1970

Type species. M. oepiki Webby, Moors, and McLean, 1970.

Diagnosis. Raphiophorid genus exhibiting subquadrate to clavate glabella, with large, forwardly expanding frontal lobe, often a median tubercle, and postero-lateral lobes; shallow transglabellar furrow divides frontal lobe from small basal median lobe, extending laterally into deep, slot-like linked lateral glabellar furrows *1p* and *2p*; eye tubercle on fixed cheek lies close to axial furrow and opposite short, transverse lateral glabellar furrow *3p*. Fixed cheeks united in front by typically rather narrow, flattened preglabellar field. Narrow anterior border and prominent anterior border furrow confined to free cheeks, the latter also connected across mid-line; narrow doublure not cut by suture. Well-defined posterior border and posterior border furrow. Long, slender, gently curved genal spine with dorsal and ventral longitudinal furrows giving hour-glass shaped cross-section. Thorax of six segments, similar to that of *Dionide*, except for more zigzag-shaped axial furrows. Pygidium prominently segmented, of two distinct dimorphic types—one subtriangular, short (sag.), less than length of cephalon, usually with eight–nine axial rings and five pleural ribs, and the other sub-semicircular, equal to cephalon or longer (sag.), typically with 16–20 axial rings and eight–ten pleural ribs.

Discussion. The discovery of large, almost complete specimens exhibiting a *Malongullia*-type cephalon and thorax, but with much expanded pygidium, occurring in the same beds at two different localities as the original *M. oepiki* (now dimorph A), has necessitated the emendation of the original conception of the genus and species given by Webby, Moors, and McLean (1970). Previously, isolated, poorly preserved, large pygidia were known from Trilobite Hill but could not be assigned to any known form. Additional collecting at Copper Mine Creek, and north of Cheeseman's Creek has revealed that there is in fact an association of the two forms in the same beds of the Malongulli Formation, and they clearly seem to represent dimorphs. Details of the differences between the two forms is given in a preceeding discussion of the dimorphism (p. 214).

M. oepiki (dimorph B) exhibits close similarities to the type species of *Edmundsonia*, *E. typa* Cooper, 1953, from the Lower Edinburg Formation and equivalents (Porterfield) of Virginia and Tennessee, but this latter form seems to lack eye tubercles and a median glabellar tubercle, and to have a much narrower (exsag.) posterior cephalic border. Although the pygidium of the type species of *Cnemidopyge* Whittard, 1955, *C. nuda* (Murchison) from the uppermost Llandeilo beds of the Builth area, Wales (Hughes 1969), closely resembles that of *M. oepiki* (dimorph B), other features such as the frontal glabellar spine, the lack of eye tubercles, and the much narrower postero-lateral lobes readily distinguish it.

The type species of *Ampyxinella* Koroleva, 1959, *A. rugosa* (Kolova) from the 'Middle' Ordovician of northern Kazakhstan (Weber 1948) is closely related to *Malongullia oepiki*, but not congeneric as Kobayashi and Hamada (1971, p. 133) have claimed. It has eye tubercles and six thoracic segments as in *M. oepiki*, but is distinguished by exhibiting a prominent anterior border furrow and part of the anterior border on the cranidium, and much deeper, curving caecae on fixed cheeks, by apparently lacking a clearly differentiated posterior border and posterior border furrow, and by having a thorax with a relatively broader (tr.) axis, with more pronounced taper posteriorly. In addition, it differs from *M. oepiki* (dimorph A) in having a much broader (sag. and exsag.) preglabellar area, and a more acutely tapering axis and fewer, broader pleural ribs on the pygidium. *M. oepiki* (dimorph B) has a similar broad preglabellar area, but even it differs in showing a pair of small tubercles, and the pygidium is completely different. *Ampyxina biloba* Tschugaeva from the Kopalin and Karakan horizons (Llanvirn to Lower Llandeilo) of Kazakhstan, one of the species assigned by Koroleva (1959) to *Ampyxinella*, is described by Tschugaeva (1958, p. 35) as having only five thoracic segments. Apart from this feature, it bears close similarities to *M. oepiki*, and may have been representative of the stock from which the Australian Caradoc genus evolved.

Whittington and Hughes (1972, p. 273) have suggested that *Malongullia* should be grouped with the Endymioniidae rather than the Raphiophoridae. The species of *Endymionia* Billings, 1865 from the Table Head Formation and correlatives (Llanvirn) of Newfoundland and Quebec (Whittington 1965), differ fundamentally from *M. oepiki* in lacking eye tubercles and a differentiated basal median lobe, and in having seven thoracic segments. However, a number of unusual features are shared by the two genera and suggest a close relationship. For instance, the presence of a pair of small tubercles on the preglabellar field and the single, median tubercle on the glabella. Such similarities probably merely stress the close relationships between the two families.

Although showing resemblances to species of *Dionide* Barrande, 1847 (see Whittington 1952; Whittard 1958), *M. oepiki* (dimorph B) differs basically in lacking a bilaminar pitted fringe, and in having a small basal median lobe on the glabella and definite eye lobes on the cheeks. The thorax is similar to that of *Dionide*, but for the markedly zigzag-shaped axial furrows. Pleural ribs on the anterior part of the pygidium of *M. oepiki* (dimorph B) have a slight concave forward curvature, in contrast to the typical convex forward curvature of species of *Dionide*.

Malongullia oepiki Webby, Moors, and McLean, 1970

Plate 30, fig. 12; Plate 31, figs. 4–12; Plate 32, figs. 1–6

1970 *Malongullia oepiki* Webby, Moors, and McLean, p. 882, pl. 125, figs. 1–12 (dimorph A only).

Additional material of dimorph A. Eleven specimens (SUP 20908a–b, 26947–26949, 27900, 27902a–b, 27911, 27913–27914) from the Malongulli Formation at Copper Mine Creek, and six specimens (SUP 27904, 27905c, 27906–27909) from the Malongulli Formation near Mirrabooka homestead, north of Cheeseman's Creek Post Office.

Supplementary description of dimorph A (Pl. 30, fig. 12; Pl. 31, fig. 12; Pl. 32, figs. 1–4). Compression seems to have caused some specimens to break and flex along lines between lateral glabellar furrows, and to give accentuated differentiation of frontal and postero-lateral lobes of the glabella (Webby *et al.* 1970, pl. 125, figs. 3, 9–10). In other, less crushed, specimens the frontal lobe is less clearly separated from the postero-lateral lobes (Webby *et al.* 1970, pl. 125, figs. 2, 4, 6–8). Lateral glabellar furrows *1p* and *2p* appear to form a connected, deep, curved, slit-like, posterior impression, *1p* directed anteromedially between postero-lateral and basal median lobes, and *2p*, extending antero-laterally from oblique intersection with *1p*, as short, deep, slot between posterior part of frontal and postero-lateral lobes; broad, shallow transglabellar furrow directed medially from junction of *1p* and *2p*, isolating small, basal median lobe from frontal lobe. Anteriorly, just inside axial furrow, and just behind mid-length (exsag.) of eye tubercle, short, almost transverse, less deeply impressed lateral glabellar furrow *3p*. Tiny, rounded apodemal pits developed at lateral ends of occipital furrow of paratype SUP 7920.

Exsagittally elongated, ovate, gently raised eye tubercle situated on fixed cheek next to axial furrow, and well inside facial suture. Well-preserved specimen, SUP 27909, exhibits fine granulation on dorsal surface of fixed cheek and glabella, including inner side of eye tubercle, but not outer side which may have been occupied by visual area. No lenses seen. Lateral pit placed near extremity of posterior border furrow, just inside sharply rounded genal angle.

Facial suture runs forward and inward from genal angle towards anterior margin, presumably meeting its counterpart in smooth curve between narrow anterior border and preglabellar field; posteriorly, it intersects posterior margin just behind lateral pit. Anterior and lateral border narrow, continuous, delimited by prominent anterior and lateral border furrow; border furrow apparently in continuity with a less strongly indented dorsal, longitudinal furrow on genal spine (Pl. 32, fig. 3). Narrow doublure connects free cheeks anteriorly; no median or connective sutures crossing it; horizontal anteriorly and antero-laterally, divided into relatively broad, flattened outer part, and narrow, sharp, ridge-like, inner part; anteriorly, doublure widens (sag. and exsag.) slightly towards mid-line; posteriorly, beneath prolongation of free cheek, it expands to form depressed, triangular area flanked by straight, lateral and posterior, and curved antero-median ridges (Pl. 30, fig. 12; Pl. 32, fig. 2); no doublure along inner part of posterior border. Long, slender genal spines have fairly persistent dorsal and ventral, longitudinal furrows, giving an hour-glass shaped cross-section; ventral longitudinal furrow dies out proximally; not continuous into depressed, triangular area beneath genal prolongation; obliquely aligned rows of fine granules cover surface of genal spines.

Apodemal pits of thorax gently crescent-shaped (concave forward) to transverse slots, set well inside axial furrow; anterior pair on macropleural segment more obliquely placed. On pygidium, six to seven pairs of transverse (slightly crescent-shaped), slot-like apodemal pits occur, decreasing in size posteriorly. One pair of small, oval muscle scars developed on anterior side of second pair of apodemal pits (SUP 27904); from constriction of first axial ring, this pair of scars may have been linked across mid-line. Second, smaller pair of isolated muscle scars occurs in front of third pair of apodemal pits. Pattern of fine granules along raised terrace lines of posterior border (SUP 27904).

Material of dimorph B. Seven specimens (SUP 19945, 20915, 26940–26941, 26942a, 26943–26944) from the Malongulli Formation at Copper Mine Creek, two specimens (SUP 19913, 20901) from the same horizon at Trilobite Hill, and six specimens (SUP 26933–26934, 26936–26938, 27905a) from the Malongulli Formation near Mirrabooka homestead, north of Cheeseman's Creek Post Office.

Comparative description of dimorph B (Pl. 31, figs. 4–11; Pl. 32, figs. 4–6). Exoskeleton ranges from 4·3 to 41 mm in length (sag.) and from 5·8 to 41 mm in width (measured across cephalon). Subrounded outline, with long, gently curved genal spines, projecting well beyond rear of pygidium. Cephalon sub-semicircular. Thorax about two-thirds length of cephalon. Pygidium subequal or slightly longer than cephalon in adult forms.

Glabella subquadrate in outline; narrowest across occipital ring; prominent broad, convex frontal lobe expands rapidly forwards to almost three times width posteriorly; flanked in posterior part by pair of elongated, suboval postero-lateral lobes, seemingly accentuated by crushing, and behind by short, narrow, basal median lobe. Probably because of crushing, lateral glabellar furrows appear as narrow, deep troughs, but may have originally been wider muscle areas; lateral glabellar furrows as in *M. oepiki* (dimorph A). Median tubercle not clearly developed in larger forms, but present on elevated part of frontal lobe of one small specimen (Pl. 31, fig. 11). Axial furrows moderately well formed, in continuity anteriorly with preglabellar furrow. No anterior pits seen. Occipital ring narrow (sag. and exsag.), gently convex backward, with steeply inclined posterior margin and gentle forward slope into broad, shallow occipital furrow.

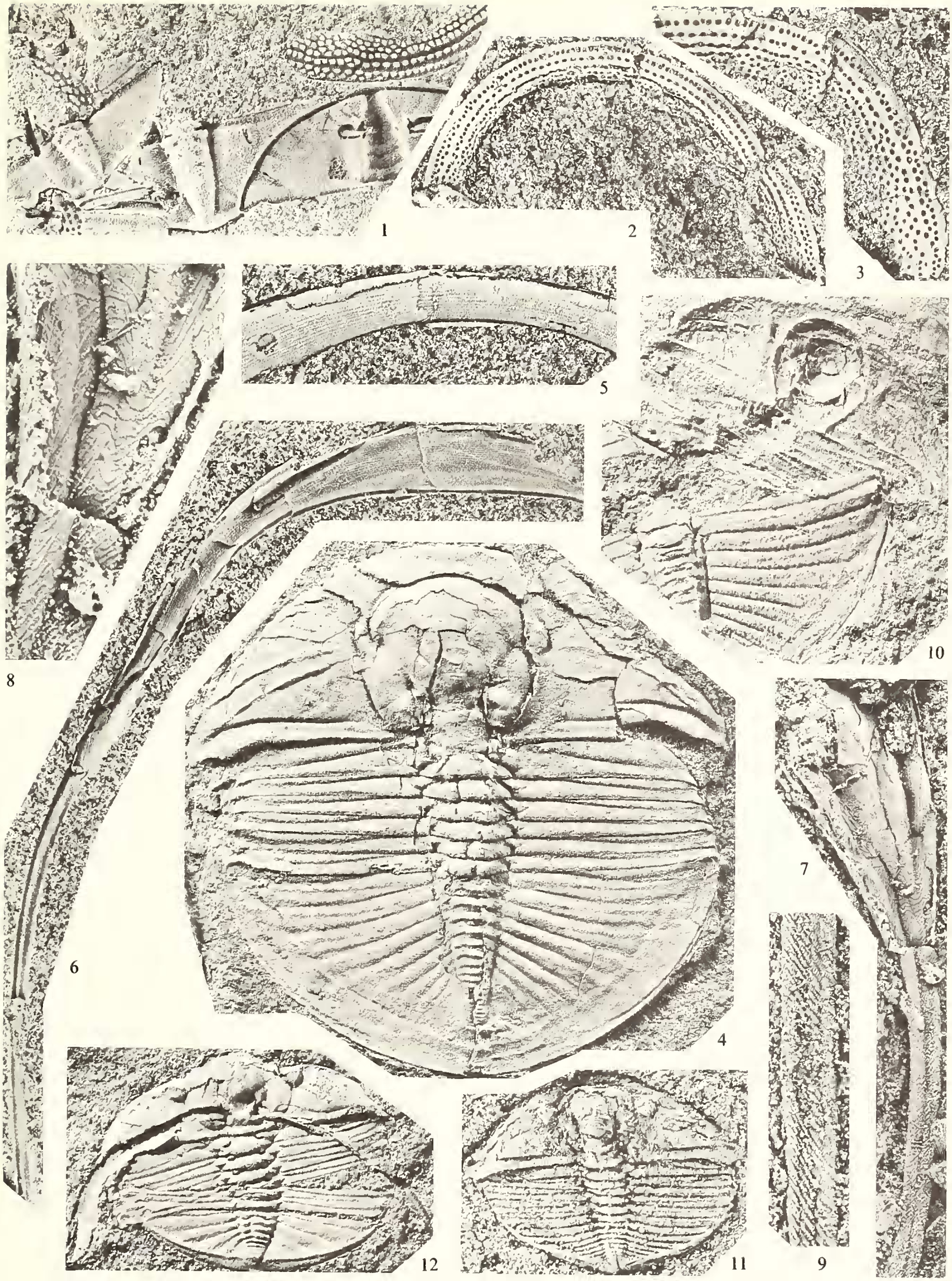
Fixed cheeks subtriangular, gently convex; eye tubercles ovate, situated on fixed cheek close to axial furrow, opposite lateral glabellar furrow *3p*. Two gently diverging caecae extend outward from posterior portion of eye tubercle towards genal angle; less conspicuous anastomosing ridges developed on fixed cheek antero-laterally. Moderately broad (sag. and exsag.), flattened preglabellar field exhibits pair of small tubercles just in front of preglabellar furrow. Inner part of posterior border transverse and relatively broad (exsag.), with flattened dorsal surface;

EXPLANATION OF PLATE 31

Figs. 1–3. *Parkesolithus dictyotos* sp. nov., from the Malongulli Formation. 1, from near Mirrabooka homestead, north of Cheeseman's Creek; 2–3, from Copper Mine Creek. 1, view of three pygidia (one inverted) and part of lower lamella of fringe, paratypes SUP 26906a–d, ×2. 2, ventral view of latex cast of lower lamella, paratype SUP 26924, ×2·5. 3, ventral view of latex impression of part of lower lamella, paratype SUP 26926, ×4.

Figs. 4–11. *Malongullia oepiki* Webby, Moors, and McLean 1970 (dimorph B) from the Malongulli Formation. 4–9, from Copper Mine Creek; 10–11, from near Mirrabooka homestead, north of Cheeseman's Creek. 4, dorsal view of latex impression of entire exoskeleton lacking free cheeks, SUP 26940, ×2. 5, ventral view of part of cephalic doublure, SUP 26942a, ×4. 6, dorsal view of doublure linking free cheeks and genal spine, SUP 19945, ×2·5. 7–8, dorsal and enlarged dorsal views of latex impression of part of right free cheek and genal spine, SUP 19945. 7, ×4; 8, ×10. 9, enlarged view of part of genal spine showing pattern of micro-ornamentation, SUP 19945, ×8. 10, view of dorsal surface of part of pygidium, and undersurface of cranidium, SUP 26936, ×3·5. 11, dorsal view of latex cast of small holaspid, SUP 26934, ×7.

Fig. 12. *Malongullia oepiki* Webby, Moors, and McLean 1970 (dimorph A) from the Malongulli Formation at Copper Mine Creek. Dorsal view of typical, almost complete exoskeleton, SUP 27902a, ×4.



WEBBY, *Parkesolithus*, *Malongullia*

expanding and backwardly curved distally. Posterior border furrow dies out approaching axial furrow; lateral pit situated at distal end of furrow, just inside sharply rounded genal angle.

Doublure more or less horizontal, widest (sag. and exsag.) anteriorly across mid-line; outer margin evenly curved; inner margin straighter, more transverse across mid-line; divided into broad, gently convex to flattened outer part, and narrow, sharply ridged inner part, both exhibiting more or less continuous, fine terrace lines running parallel to margins. Anterior and lateral border furrow prominent and continuous around margin, but appears to die out in prolongation; not clearly shown to be in continuity with dorsal longitudinal furrow of genal spine; dorsal and ventral longitudinal furrows fairly persistent along spine as in *M. oepiki* (dimorph A). Sinuous rows of raised lines borne on prolongation of free cheek; gradation into inclined rows at about 45° to exsagittal line on genal spine (Pl. 31, figs. 7–9); rows become progressively more clearly granulated distally, and tend to be more regular and close spaced on outer side of spine; a V-shaped pattern of rows may occur across a longitudinal furrow (Pl. 32, fig. 4); in some parts of genal spine, rows of granules appear more like rows of short spines. Regular rows of fine granules also occur along raised, dorso-posterior margin of posterior border, and on most elevated part of frontal lobe, in vicinity of median tubercle.

Thorax of six segments, sub-rectangular, with zigzag-shaped axial furrow; usually about three-and-one-half times wider than long, but approximately four times in small holaspid (Pl. 31, fig. 11); anterior segment longer than succeeding ones. Each axial ring as in *M. oepiki* (dimorph A), with prominent, small antero-lateral lobes; some antero-lateral lobes exhibit longitudinal creases which seem to have formed by compression. Articulating half ring, in front of sharply grooved articulating furrow, gently convex forwards, about two-thirds length (sag.) of axial ring. Transverse rows of fine granules run along raised, dorso-posterior part of anterior three axial rings. Anterior pleurae slope backwards and outwards from fulcrum to pointed, postero-lateral tips; succeeding pleurae usually exhibit rather blunter terminations. Pleural furrows as in *M. oepiki* (dimorph A).

Pygidium sub-semicircular, with straight anterior margin and sharply rounded antero-lateral corners; two to two-and-one-half times wider than long; four times wider than long in small holaspid (Pl. 31, fig. 11). Axis convex, tapering gradually posteriorly, with rounded end just inside posterior border, except in small specimens which have axis extending back to border. Usually from 16 to 20 axial rings, the last being barely recognizable; small specimens exhibit only 10–11. Up to seven pairs of linked, oval muscle scars on ring furrows of anterior half of pygidial axis; pattern of joined pairs of muscle scars medially, and lateral slopes to axial furrows distally gives this part of axis a trilobed form. Up to nine pairs of isolated, oval muscle scars are developed on posterior ring furrows, becoming progressively smaller to rear. Pleural field horizontal, usually with eight–ten gently convex to flattened ribs, the first three–four with slight forward concavity, the remainder directed progressively more strongly backwards to rear; pleural furrows more strongly impressed towards axial furrow, weakening distally; occasionally impersistent, rather faint interpleural furrows developed on pleural ribs, especially anteriorly. Irregular hummocky areas on posterior part of pleural field and immediately behind axis perhaps suggestive of pygidial caecae (Pl. 32, figs. 5–6). Broad, flattened postero-lateral border; probably originally, prior to compression, inclined backwards and outwards. Backward deflection of inner edge of posterior border across mid-line; fine terrace lines on border, running subparallel to postero-lateral margin.

A summary of the differences between dimorphs A and B has been given in a preceding section (p. 214).

Family CHEIRURIDAE Hawle and Corda, 1847
Genus SPHAEROCORYPHE Angelin, 1854

Type species. S. dentata Angelin, 1854; subsequent designation of Vogdes 1890.

Sphaerocoryphe exserta sp. nov.

Plate 33, figs. 1–9

Material. Holotype (SUP 27915) and five paratypes (SUP 27916–27920) from Ordovician limestone at Billabong Creek. All specimens are silicified.

Description. Large, bulbous, elevated frontal lobe occupying virtually entire length of glabella, rising sharply just in front of occipital ring; very short, small, rather inconspicuous, gently convex, triangular basal lobes (*1p*) isolated by weak axial furrows, more or less transverse gently depressed occipital furrow, and smooth, backwardly and inwardly curving *1p* furrows. Occipital furrow passes laterally into very deep, prominent apodemal pits. Frontal lobe raised about four or five times higher than dorsal crest of convex occipital ring above adjacent posterior border. Frontal lobe occupies about three-quarters of palpebral width; length (sag.) varies from 5·1 to 8·5 mm, and width from 6 to 9 mm. Width across basal lobes about one-half of palpebral width.

Fixed cheek incomplete, apparently originally subtriangular in shape, sloping out and back from narrow (exsag.), raised, crescentic, almost transversely aligned, palpebral lobe, situated just in front of intersection of axial and *1p* furrows; prominent, sharp palpebral furrow along rear side of lobe, leading outwards and downwards into lateral border furrow. Flanked in front by posterior branch of facial suture which extends antero-laterally on to lateral border and then deflected backwards. Lateral border furrow prominent but virtually dying out near genal angle; posterior border furrow deeply impressed, but also dying out toward genal angle. Posterior border convex, flat on inner part, becoming gently convex outwards, widening (exsag.) slightly distally, and continuous into strong, gently arched genal spine. Estimated overall width across genal spines about 23 mm, i.e. about twice width between fulcra of either side at posterior border. Prominent, raised, straight, horizontal, posterior flange, and fulcral socket extends outward from axial furrow only to about two-thirds total length (tr.) of posterior border. Narrow doublure beneath occipital ring extends about one-third of sagittal length forwards; not represented beneath posterior border, but expands outward from fulcrum on to genal spines and over short, stubby downward and antero-laterally directed lateral spine on lateral border. Surface of cephalon exhibits fine granulation.

Hypostome and thoracic segments have not yet been found.

Pygidium excluding genal spines, approximately subtriangular in outline; width, measured between fulcra on anterior edge, just less than twice sagittal length. First segment appears like normal thoracic segment with pair of curving backwardly and downwardly directed pleural spines (anterior pleural spines). Anterior margin straight and horizontal with prominent anterior, articulating flange. Axial furrows weakly impressed, subparallel anteriorly, but tapering rapidly together in posterior half of pygidium. Four convex axial rings, and small terminal piece; first two similar in size, second two decreasing considerably in size; ring furrows deepen and broaden laterally into large apodemal pits, though pits of first ring furrow not so prominent. Articulating half ring convex, extending forward to about one-half sagittal length of axial ring in front of first ring furrow. First axial ring arched convexly forwards partly exposing fused, incipient second articulating half ring and second ring furrow. Pleural fields narrow posteriorly into moderately well-defined, open V-shaped posterior border behind axis; weak pleural furrow between first and second segment, between bases of small, anterior pleural spine and very large, postero-lateral pleural spine, aligned on second segment and directed outwards and backwards. Doublure extends beneath posterior and lateral borders, but narrows toward antero-lateral angles; deflected on to anterior and postero-lateral pleural spines and into additional pair of short, pointed posteriorly directed border spines (Pl. 33, figs. 5–6). Doublure also forms short, forward and upward, pointed, tongue-like extension of inner margin medially (Pl. 33, fig. 7). On undersurface, four pairs of large tear-drop shaped apodemes, broadest and deepest near axial furrows; posterior pair smaller in size. Surface of pygidium finely granulate.

Remarks. Poor and fragmentary preservation of the bulk of the described European and North American material makes comparisons with the undistorted, silicified New South Wales specimens difficult. Some fifteen European Caradoc–Ashgill species (six from various horizons at Girvan, Scotland) and six North American 'Chazy–Trenton' species of *Sphaerocoryphe* have been recorded (Lane 1971; Shaw 1968). Dean (1971) also indicated the presence of an unnamed species in the 'Ashgill' of Quebec. Only the silicified material of *S. goodnovi* Raymond from the Chazyan of New York (Shaw 1968) can be adequately compared, and it differs markedly from *S. exserta*. The posterior part of the glabella is less constricted, basal lobes (*1p*) are more prominent, and the bulbous frontal lobe has less dorsal elevation. There is marked narrowing from occipital ring (sag.) to inner part of the posterior border (exsag.), less well differentiated axial rings and apodemal pits on the pygidium, and a much more coarsely granulated exoskeleton (Shaw 1968).

Among European forms, *S. pemphis* Lane (1971) from the Balclatchie Beds (Middle Caradoc) of Girvan, Scotland, and *S. thomsoni* (Reed) from the Drummuck Group (Ashgill) of Girvan are both readily distinguished by having two cephalic lateral spines, more prominent basal lobes (*1p*), and a much less conspicuous posterior pygidial border (Lane 1971). *S. globiceps* (Portlock) from the 'Caradoc' of Desertcreat, Northern Ireland also has much more prominent basal lobes (*1p*), a more elongated glabella, and apparently less conspicuous pleural areas between diverging pleural spines on the pygidium (Lane 1971). Both *S. psiles* Tripp from the Craighead Mudstones (Middle–Upper Caradoc) of Girvan and *S. akimbo* Tripp from the

Upper Stinchar Limestone (Lower Caradoc) of Girvan have like *S. exserta* only one pair of cephalic lateral spines. However, *S. psiles* has more prominent basal lobes (*1p*), a longer, more slender posterior part of glabella, and a weakly defined pygidial axis (Tripp 1954). *S. akimbo* has more slender, curved genal spines, and a more coarsely granulate frontal lobe and pygidium (Tripp 1967). *S. punctata* (Angelin) from the Boda Limestone (Ashgill) of Sweden, the Chair of Kildare, Ireland, and probably from Keisley, northern England, has a less dorsally elevated and constricted posterior part of the frontal lobe, more conspicuous basal lobes (*1p*), more prominently pitted fixed cheeks, and a tuberculate frontal lobe (Warburg 1925; Dean 1971). *S. erratica* Mannil (1958), from the Pirgu (F_{Ic}) horizon of Estonia bears the closest resemblance of the Baltic species, but also has a more coarsely granulate frontal lobe.

The proximity of the bulbous frontal lobe to the occipital ring which distinguishes *S. exserta* from most other species of *Sphaerocoryphe* recalls the genus *Hemisphaerocoryphe*. The type species, *H. pseudohemicranium* (Nieszkowski) from the Jöhvi (D_I) horizon of Estonia, however, has a more squat frontal lobe, more conspicuous basal lobes (*1p*), a relatively much wider (tr.) occipital ring, and it lacks lateral spines (Öpik 1937). Another species, *H. granulata* (Angelin) from the Kullsberg and other equivalent limestones of Sweden, has more closely comparable cranidial proportions, but also lacks lateral cephalic spines and has a tuberculate glabellar ornamentation (Warburg 1925). Furthermore, comparisons with the pygidium of *Hemisphaerocoryphe* cannot be made, as it remains unknown.

Family ENCRINURIDAE Angelin, 1854
Genus ENCRINURASPIS Webby, Moors, and McLean, 1970

Type species. E. optimus Webby, Moors, and McLean, 1970.

Encrinuraspis optimus Webby, Moors, and McLean, 1970

Plate 32, figs. 7–10

1970 *Encrinuraspis optimus* Webby, Moors, and McLean, p. 884, pl. 126, figs. 1–16.

Material. Five specimens (SUP 18907, 20906–20907, 20912b, 28911b) from the Malongulli Formation at Copper Mine Creek. A specimen (SUP 25902) also occurs in the Malongulli Formation of the Cheeseman's Creek area.

Supplementary description. Preglabellar furrow separates frontal lobe of glabella from preglabellar field; commences at axial furrow between prominent anterior pit and lateral glabellar furrow *3p*, and curves evenly forward and inward to near midline where it is deflected downward and slightly forward into small, V-shaped medial extension, and upward and backward into short, slot-like median longitudinal furrow on anterior margin of frontal lobe. Preglabellar field cut by anterior branch of facial suture, which crosses axial furrow just in front of anterior pit, and curves evenly across preglabellar field, drawing progressively closer to preglabellar furrow medially, almost cutting tip of V-shaped median extension (Pl. 32, fig. 7). Rostral plate not seen but presumed to be very narrow, as in *Encrinuroides*. Preglabellar area on free cheeks forms enlarged, gently convex, subrectangular lobe, steeply declined, bounded dorsally by gently curving anterior branch of facial suture, medially by connective suture, and laterally by broad, deep axial furrow. Anterior border furrow separates preglabellar area from anterior border, but dies out about two-thirds distance to connective suture (Pl. 32, fig. 10). Anterior border narrows towards connective suture; may be differentiated medially from preglabellar area in absence of anterior border furrow by lack of tubercles. Doublure appears to form as rolled extension of anterior and lateral borders. Apodemes prominent below lateral ends of occipital furrow; weakly developed beneath lateral glabellar furrows *1p* and *2p*.

Eye lobe raised, reniform in outline, with steeply backward and inwardly sloping palpebral lobe clearly delimited from gently convex, pitted, L-shaped area of fixed cheek by arcuate palpebral furrow. Broad basal part of eye lobe on free cheek consists of steeply inclined eye socle surmounted by convex, crescent- to oval-shaped visual surface composed of numerous, small hexagonal eye facets, occupying somewhat more than one-half total height of eye lobe and slightly more than three-quarters of length (exsag.) of eye lobe (Pl. 32, figs. 8–9).

Both anterior and lateral borders and preglabellar area of free cheek show fine granulation on external surfaces; preglabellar area in addition exhibits tubercles, and sometimes granules may appear on individual tubercles or a centrally placed pit; inside lateral border of free cheek, excluding eye socle, there may be pits as well as granules.

Remarks. To the original diagnosis of the genus *Encrinuraspis* given by Webby, Moors, and McLean (1970, p. 883) should be added the important distinguishing features of the moderately large, but not inflated or bulbous, frontal lobe, and the anterior branch of the facial suture obliquely intersecting the preglabellar field, the

EXPLANATION OF PLATE 32

Figs. 1–3. *Malongullia oepiki* Webby, Moors, and McLean 1970 (dimorph A) from the Malongulli Formation. 1–2, from Copper Mine Creek. 3, from near Mirrabooka homestead, north of Cheeseman's Creek. 1, ventral view of doublure linking free cheeks, SUP 27902b, ×6. 2, dorsal view of right free cheek, showing doublure and part of genal spine, SUP 27913, ×8. 3, dorsal view of latex cast of part of cephalon and thorax, SUP 27906, ×8.

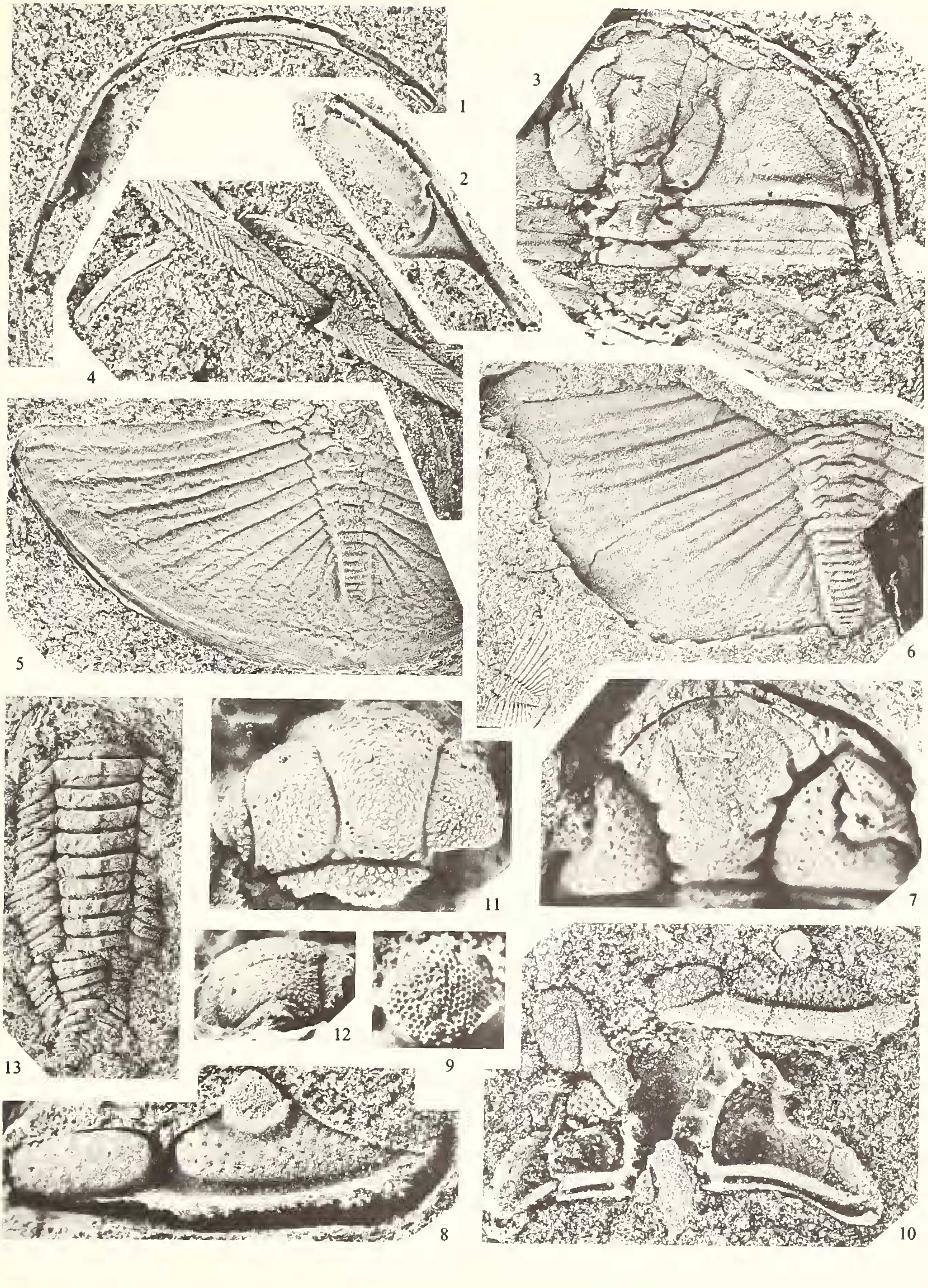
Fig. 4. *Malongullia oepiki* Webby, Moors, and McLean 1970 (dimorphs A and B) from near Mirrabooka homestead, north of Cheeseman's Creek. View of cephalic doublure of dimorph A, SUP 27905c, and of part of genal spine of dimorph B, SUP 27905a, ×9.

Figs. 5–6. *Malongullia oepiki* Webby, Moors, and McLean 1970 (dimorph B) from near Mirrabooka homestead, north of Cheeseman's Creek. 5, dorsal view of internal mould of incomplete pygidium, SUP 26938, ×4. 6, dorsal view of internal mould of part of large pygidium, SUP 26937, ×3. Note small pygidium of similar dimorph at bottom left of figure.

Figs. 7–10. *Encrinuraspis optimus* Webby, Moors, and McLean 1970 from Malongulli Formation of Copper Mine Creek. 7, dorsal view of internal mould of part of cephalon, SUP 20907, ×6. 8, oblique lateral view of internal mould of left free cheek, SUP 28911, ×10. 9, detailed view of visual surface of eye shown in Fig. 8, ×20. 10, view of latex impression of cranidium (ventral side) and free cheeks of SUP 18907, ×6.

Figs. 11–12. *Amphilichas encyrtos* sp. nov., from the Quondong Formation, Bowan Park Group, at Quondong. Dorsal and lateral views of cranidium, holotype SUP 21914. 11, ×4; 12, ×3.

Fig. 13. *Triarthrus* sp. from Cheesemans Creek Formation near Keenan's Bridge. Dorsal view of latex impression of part of lateral border on left free cheek, thorax and pygidium, SUP 37999, ×7.



WEBBY, *Malongullia*, *Encrinuraspis*, *Amphilichas*, *Triarthrus* preglabellar area of the cranidium thus being divided on either side of the mid-line into inwardly narrowing areas. In the type species of *Encrinuroides*, *E. sexcostatus* (Salter) from the Shoalshook Limestone (Middle Ashgill) of Pembrokeshire, and in *E. autochthon* Tripp from the *confinis* Flags (Lower Caradoc) of Kirkdominae, Girvan, the anterior branch of the facial suture runs more or less parallel to the preglabellar furrow, forming a narrow, entire, band-like preglabellar area of equal width laterally and medially, and the frontal lobe, especially in the type species, is markedly bulbous (Whittington 1950; Tripp 1962*a*).

Encrinuroides zhenxiongensis Sheng (1964) from the Yentsin Formation (Caradoc–Lower Ashgill) of Zhenxiong, north-east Yunnan, bears very close resemblances to *Encrinuraspis optimus*, and should be considered congeneric with it. It characteristically has the moderate sized, non-bulbous, frontal lobe, sharply rounded genal angles, large compact eyes, and anterior branches of the facial suture running obliquely across the preglabellar field, isolating narrow, wedge-like areas of the preglabellar field on the cranidium to either side of the mid-line as in *Encrinuraspis*. At the species level, it differs from *E. optimus* in having rather different cephalic and thoracic proportions, being wider across the posterior part of the glabella and axis of the thorax relative to the total cephalic and thoracic width, having slightly deeper and broader lateral glabellar furrows, giving stronger emphasis to lateral glabellar lobes, exhibiting a shorter (sag.) occipital ring, and fewer (only six or seven) pygidial ribs.

Encrinuraspis? sp. A

Plate 33, figs. 10–21

Material. Seven specimens (SUP 29916–29922) from the Ordovician limestone at Billabong Creek, and one specimen (SUP 29923) from the Quondong Formation at Quondong.

Description. Fixed cheek highly inflated, L-shaped, between very deep axial furrow and equally deep posterior border furrow. Posterior border smooth, more or less transverse in dorsal outline, very gently convex outward from axial furrow. Only lateral part of occipital ring preserved; arches gently upwards above level of posterior border. Posterior branch of facial suture curves outward and downward towards lateral margin well inside genal angle; anterior branch curves forward, inward, and downward towards anterior end of axial furrow. Overall rounded outline

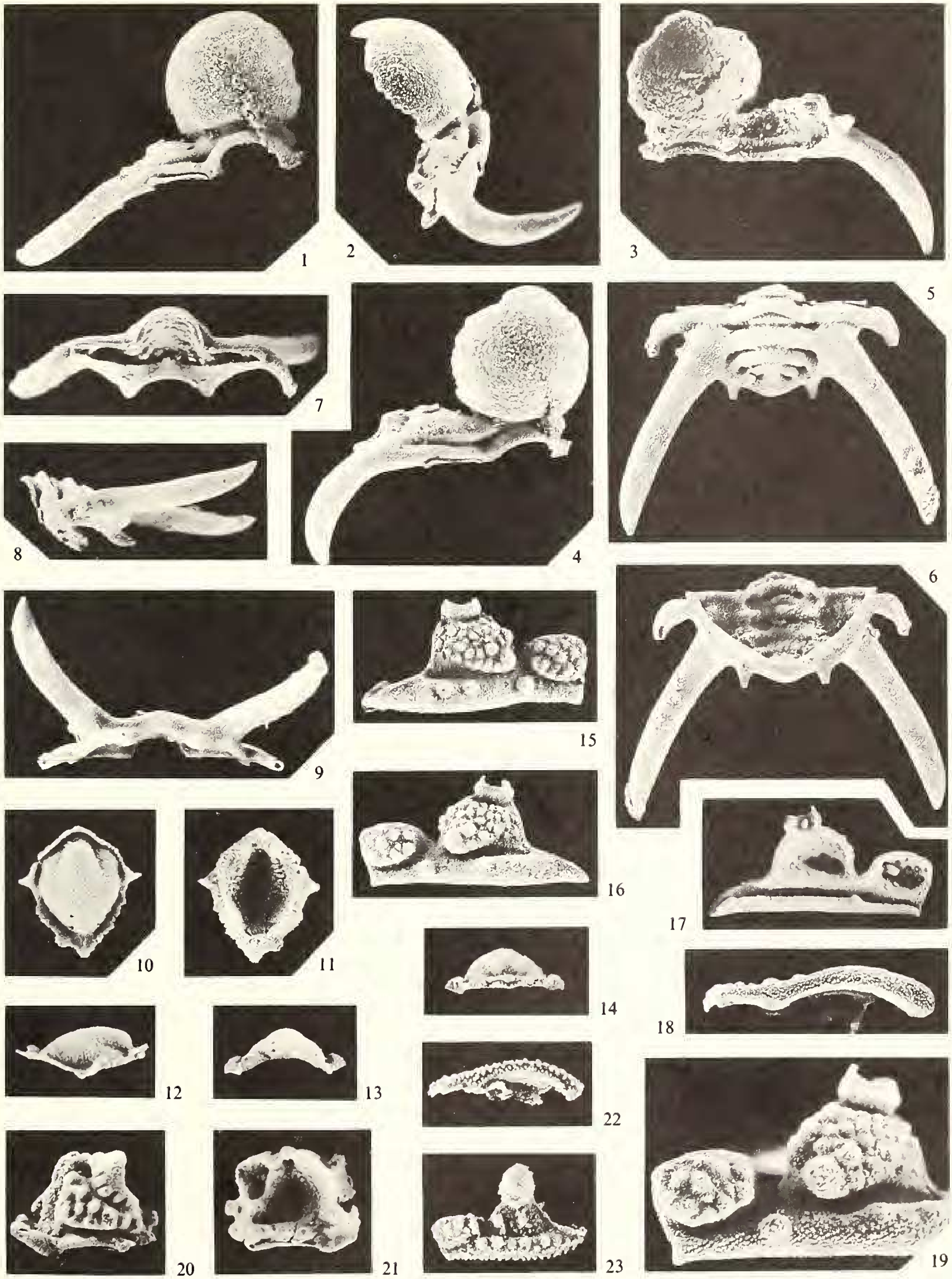
---

EXPLANATION OF PLATE 33

Figs. 1–9. *Sphaerocoryphe exserta* sp. nov., from Ordovician limestone at Billabong Creek. 1–4, posterior, lateral, ventral, and postero-lateral views of incomplete cranidium, holotype SUP 27915, ×3. 5–9, dorsal, ventral, anterior, lateral, and posterior views of pygidium; paratype SUP 27916, ×3.

Figs. 10–21. *Encrinuraspis*? sp. A. 10–19, from Ordovician limestone at Billabong Creek; 20–21, from Quondong Formation, Bowan Park Group, near Quondong. 10–14, ventral, dorsal, lateral, posterior, and anterior views of hypostome, SUP 29916, ×5. 15, lateral view of right free cheek, SUP 29920, ×3·5. 16–18, lateral, interior, and ventral views of left free cheek, SUP 29919, ×3·5. 19, enlarged lateral view of left free cheek shown in Figs. 16–18, ×6. 20–21, postero-dorsal and interior views of part of right fixed cheek, SUP 29923, ×4.

Figs. 22–23. *Encrinuraspis*? sp. B from 'brachiopod' unit of Daylesford Formation, Bowan Park Group, north-east of Quondong. Ventral and lateral views of left free cheek, SUP 29926, ×6.



WEBBY, *Sphaerocoryphe*, *Encrinuraspis*?

of eye lobe; defined by deep, curved palpebral furrow which is continuous across facial suture into well-defined furrow (socle furrow); large, raised, crescent-shaped palpebral lobe consists of lower area with row of tubercles running around edge of lobe immediately above palpebral furrow, and upper, smooth, almost conical area. Highest point of eye lobe on facial suture close to mid-point of palpebral lobe and visual surface. Inflated, L-shaped part of fixed cheek covered by moderately large tubercles.

Character of free cheek very similar to that of *E. optimus* differing only in having large tubercles on surface, and more continuous anterior border furrow medially. Anterior border furrow continues towards connective suture, swinging upwards close to suture in direction of preglabellar furrow (Pl. 33, fig. 19); axial furrow very broad, deep, separating inflated subrectangular–oval, tuberculate preglabellar area of free cheek from steeply inclined, enlarged area inside lateral border, surmounted by eye. On dorsal side preglabellar area cut sharply by curving anterior branch of facial suture. Anterior border widens postero-laterally into lateral border, usually with large tubercle situated on border approximately in line with anterior end of axial furrow; additional two moderately large tubercles on lateral border. Deep, broad lateral border furrow in continuity with anterior border furrow across anterior end of axial furrow, separating steeply inclined, inflated, tuberculate area of free cheek from lateral border; tubercles of varying sizes, including an especially large one on lower, antero-lateral part of inflated area. Well-defined smooth, convex eye socle presumably surmounted by visual surface, and separated from tuberculate area below by distinct socle furrow. Doublure beneath anterior and lateral borders more or less flattened, horizontal, as seen in side view, but with small downward deflection at antero-median tip (Pl. 33, fig. 19); formed from rolled anterior and lateral borders widening slightly posteriorly and opposite anterior end of axial furrow. Doublure beneath lateral border rolled inwards and upwards, whereas on anterior border only projecting inwards and cut by hypostomal suture (Pl. 33, fig. 17). Surface of anterior and lateral borders and doublure granulate.

Hypostome with oval outline, excluding anterior wings; maximum width about three-quarters sagittal length; inflated middle body has pronounced median anterior lobe with steep, near vertical, upward slope just behind anterior border furrow; shallow furrows to either side of steep slope of median anterior lobe; extend backward and slightly outward, becoming weaker and finally dying out just in front of anterior wings. Anterior border has broad V-shaped outline, and sharply downwardly deflected rim, broadening sutural surface of contact with adjacent anterior border of free cheek and rostral plate; anterior border furrow deep and asymmetrically V-shaped in profile, running continuously forward to mid-line from adjacent to base of anterior wings. Lateral borders more gently declined and wider, bounded by more symmetrically open, V-shaped lateral border furrows; posterior border flatter and widest medially, but imperfectly preserved margin prevents determination of original shape of border—whether it was pointed or more broadly rounded. No macula seen. Undersurface exhibits no doublure. Anterior wings situated just in front of mid-length of middle body, with only triangular, outwardly directed bases preserved; upwardly inclined wings damaged; posterior wings not shown in material studied. Ventral surface of middle body exhibits fine granulation.

Remarks. Possibly less stress should be given to ornamentation in the diagnosis of *Encrinuraspis* (Webby, Moors, and McLean 1970, p. 883) in order to accommodate the silicified materal from Billabong Creek referred to *Encrinuraspis*? sp. A, and from the lower part of the Daylesford Formation near Quondong assigned to *Encrinuraspis*? sp. B (see below). Neither the Billabong Creek nor the Daylesford material can be included with forms like the type species of *Encrinurus*, *E. punctatus* (Wahlenberg), and *E. macrourus* Schmidt, from the Silurian of Gotland (Tripp 1962*b*), because they have free cheeks exhibiting an enlarged preglabellar area separated from a continuous, well-differentiated anterior border by a well-defined anterior border furrow. *E. macrourus* has poorly differentiated, more constricted, preglabellar and anterior border areas, divided by an ill-defined, shallow anterior border furrow, which gives the anterior border a marked, medially tapering wedge-shaped appearance (Tripp 1962*b*, p. 469, pl. 66, fig. 1c). The tuberculated New South Wales forms could perhaps be regarded as representatives of the *Encrinurus multisegmentatus* species group (Tripp 1957) but these characteristically have a more uniform, coarse tuberculation over most of the cephalon, including the anterior and lateral borders. Pitting, as seen on the area of the free cheek inside the lateral border furrow of *Encrinuraspis*? sp. B, is not shown in representatives of the *E. multisegmentatus* species group. It therefore seems preferable tentatively to refer these tuberculate forms to *Encrinuraspis*. They seem to exhibit a similar relationship to the more finely ornamented *Encrinuraspis* in New South Wales, as representatives of the species of the *Encrinurus multisegmentatus* group have to *Encrinuroides* in British successions.

Encrinuraspis? sp. B

Plate 33, figs. 22–23; Plate 34, figs. 1–2

Material. Two silicified specimens (SUP 29926–29927) from the 'brachiopod' unit of the Daylesford Formation, Bowan Park Group, north-east of Quondong.

Comparative description. These specimens of free cheeks are distinguished from those of *Encrinuraspis*? sp. A by being smaller, having a row of moderate-sized tubercles along the dorso-lateral edge of the lateral border, and small, spinose tubercles on the ventro-lateral edge. The preglabellar area is also tuberculate, and the area between the eye lobe and the lateral border furrow also exhibits two or three prominent tubercles together with many small pits. The eye lobe is slightly more elevated and rounded, with the visual surface occupying the upper half. On the lower half, the eye socle exhibits on its antero-lateral corner a slightly expanded, rounded projection covered with granules. The region of the free cheek directly below the eye socle is constricted but lacks a defined socle furrow; it has a crimped appearance with vertically elongated pits. The pitting on the area of the free cheek between the eye lobe and lateral border furrow resembles that seen in *E. optimus*.

Family LICHIDAE Hawle and Corda, 1847
Genus AMPHILICHAS Raymond, 1905

Type species. Platymetopus lineatus Angelin, 1854.

Discussion. In addition to the two New South Wales species of *Amphilichas* described herein, the genus has been recorded from the Gordon Limestone of Tasmania (Whittington 1966). *Amphilichas* has a widespread distribution in Caradoc–Ashgill times in North America, Europe, and Asia, some 44 species being recorded by Tripp (1958). The genus first appeared in the Chazyan (about Llandeilo) of New York (Shaw 1968), probably derived from the closely related genus *Apatolichas* Whittington (1963) from the Lower Head (Whiterock or, in European terms, Llanvirn) of western Newfoundland. By Lower Caradoc times, *Amphilichas* has spread to Europe, Asia, and probably to Australia.

Amphilichas nasutus sp. nov.

Plate 34, figs. 3–9

Material. Holotype (SUP 27921) and two paratypes (SUP 27930–27931) from Ordovician limestone at Billabong Creek.

Description. Glabella including occipital ring of rather similar length (sag.) to maximum width, narrowing only slightly backwards; gently convex transversely between eye lobes; very convex forwards especially along sagittal line, with slight overhang of anterior border. Lateral glabellar furrows *3p* curve inward and swing evenly round into backwardly directed longitudinal furrows; about opposite mid-point of eye lobes, longitudinal furrows become obsolete, and fail to meet occipital furrow. Median, anterior lobe expands forward and comparatively sharply rounded anteriorly along mid-line; as seen in lateral profile, gently arched dorsal surface of lobe flexed sharply downwards anteriorly into gently convex, near vertical, anterior surface of lobe; at level of eye lobes, median, anterior lobe slightly wider than convex, composite lateral lobes on either side of it; median, anterior lobes narrowest at about glabellar mid-length. Occipital ring longer sagittally than laterally; occipital furrow behind median, anterior lobe straight and transverse, but laterally, behind composite lateral lobes, curving slightly backward and outward. Axial furrows curve forward and inward into anterior border furrow, and backward, from just in front of eye lobes, toward lateral ends of occipital ring. Axial, occipital, and lateral glabellar *3p* (in anterior two-thirds of its course) furrows impressed equally deeply.

Fixed cheek approximately subtriangular, strongly convex exsagittally and flattened to gently convex transversely. Eye lobe appears to have been large, situated

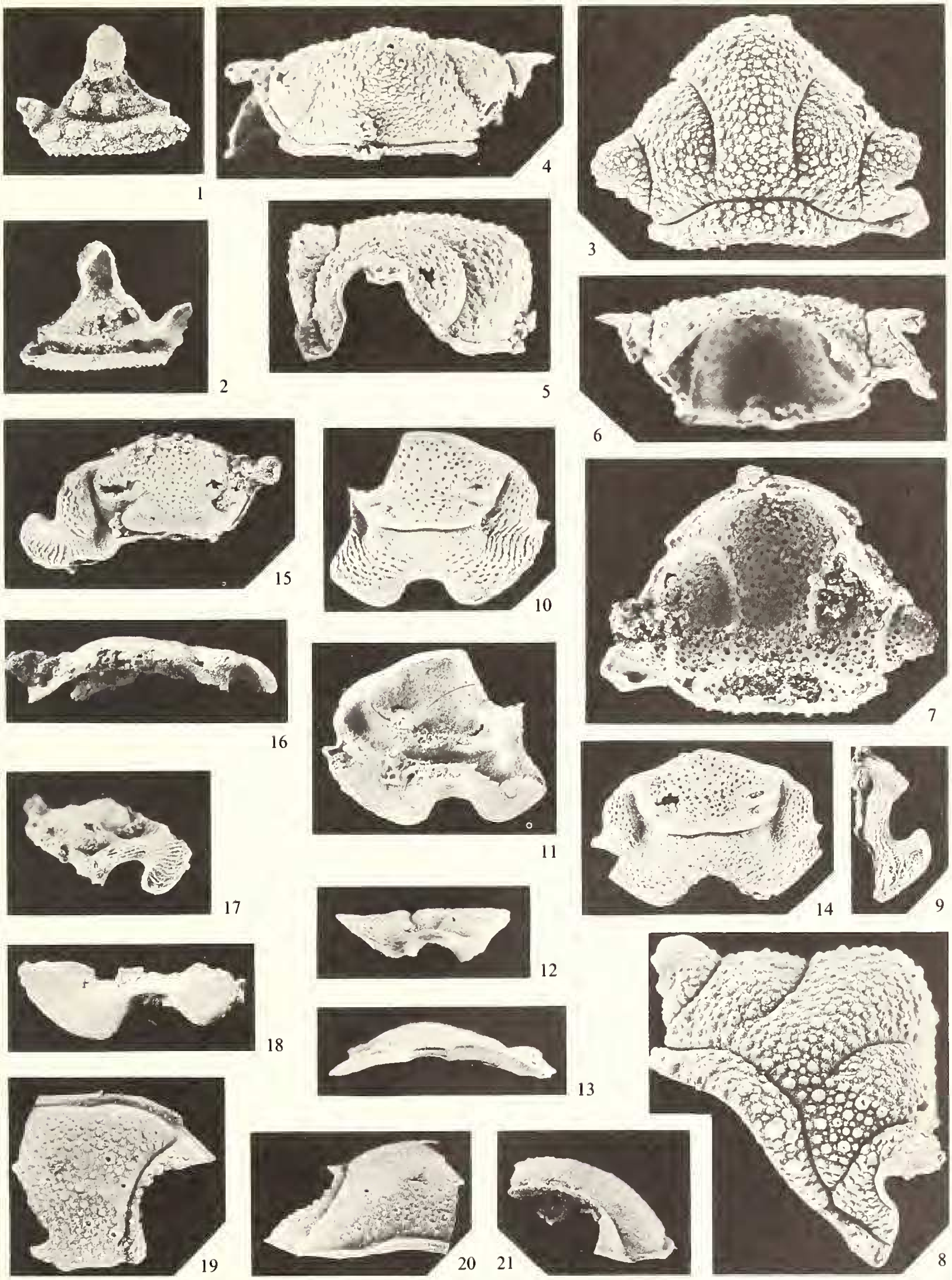
---

EXPLANATION OF PLATE 34

Figs. 1–2. *Encrinuraspis*? sp. B from 'brachiopod' unit of Daylesford Formation, Bowan Park Group, north-east of Quondong. Lateral and interior views of incomplete left free cheek, SUP 29927, ×6.

Figs. 3–9. *Amphilichas nasutus* sp. nov., from Ordovician limestone at Billabong Creek. 3–8, dorsal, anterior, lateral, posterior, ventral, and oblique dorso-lateral views of cranidium, holotype, SUP 27921. 3–7, ×3·5; 8, ×4. 9, ventral view of lateral part of hypostome, paratype, SUP 27931, ×4.

Figs. 10–21. *Amphilichas encyrtos* sp. nov., from Quondong Formation, Bowan Park Group, near Quondong. 10–13, ventral, dorsal, lateral, and posterior views of incomplete hypostome, paratype, SUP 27922, ×4. 14, ventral view of hypostome lacking lateral notches and shoulders, paratype, SUP 27923, ×3·5. 15–17, ventral anterior and oblique antero-ventral views of incomplete hypostome, paratype, SUP 27924, ×4. 18, dorsal view of posterior part of fragmentary large hypostome, paratype, SUP 27925, ×2·5. 19–21, dorsal, anterior, and lateral views of broken, incomplete cranidium, paratype, SUP 37916, ×3·5.



WEBBY, *Encrinuraspis*?, *Amphilichas*

on highest part of cheek, well out from axial furrow; broad, elevated area not differentiated; well-marked palpebral furrow and differentiated palpebral lobe only seen on rear slope. Anterior branch of facial suture runs inward and forward, then descends subparallel to axial furrow, cuts across anterior border, and turns sharply to extend in smooth curve along anterior margin of anterior border. Anterior border narrow (sag. and exsag.), horizontal, with evenly curved anterior margin. Posterior branch of facial suture curves in arc across eye lobe, then backward so as to intersect posterior margin inside presumed projection of posterior border. Posterior border narrow (tr.); inner part adjacent to occipital ring, short (exsag.) and horizontal; lengthening (exsag.) at sharp, nodular flexure of fulcrum; distally, outwardly and slightly forwardly inclined, terminating rather bluntly. Doublure seen to extend about one-third of length forward beneath occipital ring. Prominent groove developed on posterior border just below sharp flexure, presumably for reception of outer part of pleura of first thoracic segment during enrolment. External surface of cranidium covered by tubercles of varying sizes, up to 0·5 mm in diameter at bases. Rostral plate unknown.

Only lateral part of hypostome preserved. Large lateral notch (relatively slightly larger than in *A. encyrtos* sp. nov.) behind base of anterior wing, presumably through which antennule protruded, and in front of well-developed shoulder with bluntly pointed anterior tip. Faint, irregular, anastomosing lines of ventral surface of margin of lateral notch and shoulder. Doublure seen above shoulder on lateral border.

Remarks. A. nasutus appears to have the closest resemblances to *A. karakanensis* var. *disjunctus* Tschugaeva (1958) from the Anderken horizon (Lower Caradoc) of Kazakhstan, and *A. atavus* Warburg from the lower part of the Kullsberg Limestone of Dalarne (Warburg 1925, 1939), and similarly exhibits longitudinal furrows on the glabella which fail to reach the occipital furrow. However, it differs from both the Kazakhstan and Swedish forms in having a cranidium with a more acutely pointed anterior portion of the median, anterior lobe, and a more coarsely tuberculated external surface.

Amphilichas encyrtos sp. nov.

Plate 32, figs. 11–12; Plate 34, figs. 10–21

Material. Holotype (SUP 21914) and nine paratypes (SUP 27922–27929, 37916) from the Quondong Formation, Bowan Park Group, near Quondong.

Comparative description. Glabella including occipital ring slightly wider than long (sag.); subparallel-sided, narrowing slightly in front of eye lobes; convex forwards, and more gently convex transversely. Lateral glabellar furrow *3p* curves inward and backward into longitudinal furrow which is continuous to occipital furrow; inner course of longitudinal furrow directed backward and slightly inward, but close to intersection with occipital furrow deflected outward. Median, anterior lobe expanding forwards, with even convexity from highest part of glabella opposite eye lobes; narrowest just behind glabellar mid-length. Median, anterior lobe subequal (tr.) to composite lateral lobes to either side, at level of eye lobes. Axial, longitudinal, and occipital furrows, especially the latter, very deeply impressed. Fixed cheek with prominent palpebral lobe lacking tubercles. Anterior border and anterior border furrow slightly upwardly flexed medially (Pl. 34, fig. 20); in dorsal outline, median part of anterior margin transverse (Pl. 34, fig. 19). Tubercles of varying sizes, up to 0·5 mm in diameter, covering most of the surface of cranidium; includes large tubercles set at intersection of longitudinal furrows and occipital furrow.

Hypostome flattened to weakly convex, wider than long, with subtrapezoidal middle body separated from very broad lateral and posterior borders by deep, lateral, and posterior border furrows. Middle body divided by pair of short, inwardly and slightly forwardly directed middle furrows into larger, anterior, and shorter, posterior lobes. Hypostomal suture gently convex forwards, with slight V-shaped outline, bordering anterior margin of middle body; anterior border lacking. Anterior wings not preserved; seem to have extended upward from bases at antero-lateral corners. Lateral and posterior borders very broad, especially laterally; expanded out into very prominent, rounded shoulder behind large, lateral notch. Broad, gentle sag in lateral border runs from opposite posterior lobe of middle body outwards on to shoulder. Extended, flattened posterior border deeply notched medially. Pitting covers much of external surface of middle body and borders; also crudely concentric pattern of anastomosing lines on posterior and lateral borders. Doublure extends inward over much of the lateral and posterior border areas; U-shaped, median scallop on surface of doublure in front of median notch of posterior border (Pl. 34, figs. 11, 18); also downward, tongue-like deflection of inner edge of doublure medially, just behind posterior border furrow of ventral surface; with sharp, outwardly curved (concave forward) furrows running close to inner edge to either side of it.

Thus, *A. encyrtos* may be distinguished from *A. nasutus* by having a glabella with a less convex, more evenly rounded anterior part of median, anterior lobe, longitudinal furrows continuous to occipital furrow, with a prominent tubercle at each furrow intersection, medially flattened anterior margin, a non-tuberculate palpebral lobe, and a more rounded anterior edge of shoulder on hypostome.

Acknowledgements. I thank Professor H. B. Whittington and Dr. C. P. Hughes for reading and criticizing the manuscript. Dr. K. S. W. Campbell kindly read the section dealing with *Parkesolithus*. Most of the work was carried out during a period of study leave in 1971–1972 at the Sedgwick Museum, University of Cambridge, with the support of a Royal Society and Nuffield Foundation Commonwealth Bursary. Additional financial support came from a Sydney University Research Grant, and the Australian Research Grants Committee. Financial assistance from Sydney University towards publication costs is gratefully acknowledged. Much of the material was originally collected during joint studies of Ordovician successions in New South Wales by myself and Associate Professor G. H. Packham. I thank him, and also Dr. V. Semeniuk, Dr. H. T. Moors, Messrs. L. Sherwin, M. Tuckson, and C. J. Jenkins for making additional specimens available for study.

REFERENCES

ANGELIN, N. P. 1854. *Palaeontologia Scandinavica I. Crustacea formationis transitionis.* Fasc. 2, 21–92. Lund.

BANCROFT, B. B. 1933. *Correlation-tables of the Stages Costonian–Onnian in England and Wales.* 4 pp. Printed privately.

BARRANDE, J. 1847. Über das Hypostome und Epistoma zwei analoge, aber verschiedene Organe der Trilobiten. *Neues Jahrb. f. Min.* 385–399.

BILLINGS, E. 1865. *Palaeozoic fossils.* Vol. 1. *Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks.* Pp. 169–426. Geol. Surv. Canada. Montreal.

BURMEISTER, H. 1843. *Die Organisation der Trilobiten.* 147 pp. Berlin.
CAMPBELL, K. S. W. 1967. Trilobites of the Henryhouse Formation (Silurian) in Oklahoma. *Bull. Okla. Geol. Surv.* **115,** 1–68.
—— and DURHAM, G. J. 1970. A new trinucleid from the Upper Ordovician of New South Wales. *Palaeontology,* **13,** 573–580.
CHURKIN, M. 1963. Ordovician trilobites from graptolitic shale in Central Idaho. *J. Paleont.* **37,** 421–428.
CLARKSON, E. N. K. 1969. Dimorphism of the Eye in *Weberides shunnerensis* (King) (Trilobita). *In* WESTERMANN, G. E. C. (ed.), Sexual Dimorphism in Fossil Metazoa and Taxonomic Implications. *Int. Union Geol. Sci.* (*A*), **1,** 185–195.
COOPER, B. N. 1953. Trilobites from the Lower Champlainian formations of the Appalachian Valley. *Mem. geol. Soc. Amer.* **55,** 1–69.
DEAN, W. T. 1962. The trilobites of the Caradoc Series in the Cross Fell Inlier of Northern England. *Bull. Br. Mus. nat. Hist.* (Geol.), **7** (3), 65–134.
—— 1971. The trilobites of the Chair of Kildare Limestone (Upper Ordovician) of eastern Ireland. Part 1. *Palaeontogr. Soc., Monogr.* 1–60.
EMMRICH, H. F. 1844. *Zur Naturgeschichte der Trilobiten.* 28 pp. Meinigen.
GILBERT-TOMLINSON, J. 1961. Ordovician fossils from Thangoo No. 1 and Thangoo No. 1A, Western Australia. *Bur. Min. Res. Aust., Petroleum Search Sub. Act Publ.* **14,** 24–29.
GREEN, J. 1832. *A Monograph of the trilobites of North America.* 93 pp. Philadelphia.
HARRINGTON, H. J. and LEANZA, A. F. 1957. Ordovician trilobites of Argentina. *Univ. Kansas, Dept. Geol., Spec. Publ.* **1,** 1–276.
HAWLE, I. and CORDA, A. J. C. 1847. *Prodrom einer Monographie die bohmischen Trilobiten.* 176 pp. Prague.
HU, CHUNG-HUNG. 1964. The ontogeny and dimorphism of *Welleraspis lata* Howell (Trilobita). *J. Paleont.* **38,** 95–97.
—— 1971. Ontogeny and sexual dimorphism of Lower Paleozoic Trilobita. *Palaeontogr. Americana,* **7** (44), 29–155.
HUGHES, C. P. 1969. The Ordovician trilobite faunas of the Builth–Llandrindod Inlier, Central Wales. Part I. *Bull. Br. Mus. nat. Hist.* (Geol.), **18** (3), 39–103.
—— 1970. Statistical analysis and presentation of trinucleid (Trilobita) fringe data. *Palaeontology,* **13,** 1–9.
HUPE, P. 1953. Classe des Trilobites. *In* PIVETEAU, J. (ed.), *Traité de Paleontologie,* **3,** pp. 44–246. Paris.
INGHAM, J. K. 1970. The Upper Ordovician trilobites from the Cautley and Dent districts of Westmorland and Yorkshire. Part 1. *Palaeontogr. Soc., Monogr.* 1–58.
KOBAYASHI, T. and HAMADA, T. 1971. Silurian trilobites from the Langkawi Islands, West Malaysia, with notes on the Dalmanitidae and Raphiophoridae. *Geology and Palaeontology of Southeast Asia,* **9,** 87–134.
KOROLEVA, M. N. 1959. Novye rody trilobitov iz srednego i verhknego ordovika Severnogo Kazahkstana. *Dokl. Akad. Nauk. SSSR,* **124** (6), 1313–1316.
LAMONT, A. 1935. The Drummuck Group, Girvan; a stratigraphical revision, with descriptions of new fossils from the lower part of the group. *Trans. geol. Soc. Glasgow,* **19,** 288–332.
LANE, P. D. 1971. British Cheiruridae (Trilobita). *Palaeontogr. Soc. Monogr.* 1–95.
MANNIL, R. M. 1958. Trilobity semejstv Cheiruridae i Encrinuridae iz Estonii. *Geoloogia Inst. Uurim.* **3,** 165–212.
MITCHELL, A. H. and READING, H. G. 1969. Continental margins, geosynclines and ocean-floor spreading. *J. Geol.* **77,** 629–646.
MOORE, R. C. (ed.). 1959. *Treatise on Invertebrate Paleontology.* Part O, Arthropoda. xix + 560 pp. Univ. Kansas Press.
MOORS, H. T. 1970. Ordovician graptolites from the Cliefden Caves area, Mandurama, N.S.W., with a re-appraisal of their stratigraphic significance. *Proc. roy. Soc. Vict.* **83,** 253–287.
NICHOLSON, H. A. and ETHERIDGE, R. 1879. *A monograph of the Silurian fossils of Girvan in Ayrshire with special reference to those contained in the 'Gray Collection'.* Vol. 1, Fasc. 2, i–vi, 136–233. Edinburgh and London.
ÖPIK, A. A. 1937. Trilobiten aus Estland. *Acta Comment. Univ. Tartu* (*A*), **32** (3), 1–163. (*Publ. Geol. Inst. Univ. Tartu, 52*).
—— 1958. The Cambrian Trilobite *Redlichia*: organization and generic concept. *Bull. Bur. Min. Resour. Aust.* **42,** 1–50.

ÖPIK, A. A. 1963. Early Upper Cambrian Fossils from Queensland. Ibid. **64,** 1–133.

PACKHAM, G. H. 1967. The Occurrence of Shelly Ordovician Strata near Forbes, New South Wales. *Aust. J. Sci.* **30,** 106–107.

—— 1969. Ordovician System. The Geology of New South Wales. *J. geol. Soc. Aust.* **16,** 76–103.

—— and FALVEY, D. A. 1971. An hypothesis for the formation of marginal seas in the Western Pacific. *Tectonophysics,* **11,** 79–109.

PALMER, A. R. 1972. Problems of Cambrian biogeography. *24th Int. geol. Congr., sect.* **7,** 310–315.

RAYMOND, P. E. 1905. Note on the Names *Amphion, Harpina,* and *Platymetopus. Amer. J. Sci.* (*4*), **19,** 377–378.

REED, F. R. C. 1896*a*. The fauna of the Keisley Limestone, Part I. *Q. Jl geol. Soc. Lond.* **52,** 407–437.

—— 1896*b*. Woodwardian Museum notes. Notes on the evolution of the genus *Cheirurus. Geol. Mag.* (*4*), **3,** 117–123.

—— 1904. The Lower Palaeozoic trilobites of the Girvan district, Ayrshire. Part 2. *Palaeontogr. Soc., Monogr.* 49–96.

—— 1928. Notes on the Bronteidae [= Goldidae]. *Ann. Mag. nat. Hist.* (*10*), **1,** 49–78.

—— 1931. The Lower Palaeozoic trilobites of Girvan. Supplement no. 2. *Palaeontogr. Soc., Monogr.* 1–30.

RICHTER, R. and RICHTER, E. 1955. Scutelluidae n.n. (Tril.) durch 'Kleine Änderung' eines Familien-Namens wegen Homonymie. *Senck. leth.* **36,** 291–293.

—— —— 1956. Grundlagen für die Beurteilung und Einteilung der Scutelluidae (Tril.). *Senck. leth.* **37,** 79–124.

ROBISON, R. A. 1972. Hypostoma of agnostid trilobites. *Lethaea,* **5,** 239–248.

ROSS, R. J. and SHAW, F. C. 1972. Distribution of the Middle Ordovician Copenhagen Formation and its Trilobites in Nevada. *U.S. geol. Surv., Prof. Pap.* **749,** 1–33.

SCHEIBNER, E. 1972. Actualistic Models in Tectonic Mapping. *24th Int. geol. Congr., sect.* **3,** 405–422.

SELWOOD, E. B. 1965. Dechenellid trilobites from the British Middle Devonian. *Bull. Br. Mus. nat. Hist.* (Geol.), **10,** 319–333.

—— and BURTON, C. J. 1969. Possible Dimorphism in certain Devonian Phacopids (Trilobita). *In* WESTERMANN, G. E. C. (ed.), Sexual Dimorphism in Fossil Metazoa and Taxonomic Implications. *Int. Union Geol. Sci.* (*A*), **1,** 196–200.

SHAW, F. C. 1968. Early Middle Ordovician Chazy Trilobites of New York. *N.Y. State Mus. Mem.* **17,** 1–163.

SHENG, S. F. 1964. Upper Ordovician trilobite faunas of Szechuan–Kweichow with special discussion on the classification and boundaries of the Upper Ordovician. *Acta Palaeont. Sinica,* **12** (4), 537–571.

SHERWIN, L. 1970. Age of the Billabong Creek Limestone. *Quart. Notes geol. Surv. N.S.W.* **1,** 1–3.

—— 1971. Stratigraphy of the Cheeseman's Creek District, New South Wales. *Rec. geol. Surv. N.S.W.* **13,** 199–237.

SINCLAIR, G. W. 1949. The Ordovician trilobite *Eobronteus. J. Paleont.* **23,** 45–56.

SKJESETH, S. 1955. The Middle Ordovician of the Oslo region, Norway. 5. The trilobite family Styginidae. *Norsk geol. Tidsskr.* **35,** 9–28.

SKWARKO, S. K. 1962. Graptolites of Cobb River–Mount Arthur Area, North-West Nelson, New Zealand. *Trans. roy. Soc. N.Z., Geol.* **1** (15), 215–247.

SMITH, R. E. 1966. The geology of Mandurama–Panuara. *J. Proc. R. Soc. N.S.W.* **98,** 239–262.

ŠNAJDR, M. 1960. Studie o čeledi Scutelluidae (Trilobitae). *Rozpravy, Ústřed. ústav. geol.* **26,** 1–263.

STRACHAN, I. 1972. Correlation of British and Australian graptolite zones. *In* WILLIAMS, A., STRACHAN, I., BASSETT, D. A., DEAN, W. T., INGHAM, J. K., WRIGHT, A. D., and WHITTINGTON, H. B. A correlation of Ordovician rocks in the British Isles. *Spec. Pap. geol. Soc. Lond.* **3,** 10–14.

THORSLUND, P. 1940. On the Chasmops Series of Jemtland and Södermanland (Tvären). *Sver. geol. Unders.* (*C*), **436,** 1–191.

TRIPP, R. P. 1954. Caradocian Trilobites from Mudstones at Craighead Quarry, near Girvan, Ayrshire. *Trans. R. Soc. Edinb.* **62,** 655–693.

—— 1957. The trilobite *Encrinurus multisegmentatus* (Portlock) and allied Middle and Upper Ordovician species. *Palaeontology,* **1,** 60–72.

—— 1958. Stratigraphical and geographical distribution of the named species of the trilobite superfamily Lichacea. *J. Paleont.* **32,** 574–582.

TRIPP, R. P. 1962*a*. Trilobites from the *confinis* Flags (Ordovician) of the Girvan district, Ayrshire. *Trans. R. Soc. Edin.* **65**, 1-40.

—— 1962*b*. The Silurian trilobite *Encrinurus punctatus* (Wahlenburg) and allied species. *Palaeontology*, **5**, 460-477.

—— 1967. Trilobites from the Upper Stinchar Limestone (Ordovician) of the Girvan district, Ayrshire. *Trans. R. Soc. Edin.* **67**, 43-93.

TSCHUGAEVA, M. N. 1958. Trilobity ordovika Tschu-Ilijskihk gor. Ordovik Kazahkstana, III. *Trud. geol. Inst. Akad. Nauk. SSSR*, **9**, 5-138.

VALENTINE, J. W. 1971. Plate tectonics and shallow marine diversity and endemism, an actualistic model. *Syst. Zool.* **20**, 253-264.

VOGDES, A. W. 1890. A bibliography of Palaeozoic Crustacea from 1698 to 1889, including a list of North American species and a systematic arrangement of genera. *Bull. U.S. geol. Surv.* **63**, 1-177.

WARBURG, E. 1925. The trilobites of the Leptaena limestone in Dalarne. *Bull. Geol. Instn Univ. Uppsala*, **17**, 1-446.

—— 1939. The Swedish Ordovician and Lower Silurian Lichidae. *K. Svenska Vetens. Handl.* (*3*), **17** (4), 1-162.

WEBER, V. N. 1945. O rode *Thysanopeltis* Corda i nekotoryhk Uralbskihk Bronteidae. *Materialy VSEGEI, paleontologija i stratigrafija. Vyp.* **4**, 24-45.

—— 1948. Monografii po paleontologii SSSR. Tom 69, Trilobity Silurijskihk oflozhenij SSSR. Vyp. 1. Nizhnesilurjskie trilobity. *Vses. Nauchno-issled. geol. inst.* (*VSEGEI*). Minist. geol. SSSR, 1-113.

WEBBY, B. D. 1969. Ordovician stromatoporoids from New South Wales. *Palaeontology*, **12**, 637-662.

—— 1971. The trilobite *Pliomerina* Chugaeva from the Ordovician of New South Wales. Ibid. **14**, 612-622.

—— 1973. *Remopleurides* and other Upper Ordovician trilobites from New South Wales. Ibid. **16**, 445-475.

—— MOORS, H. T. and MCLEAN, R. A. 1970. *Malongullia* and *Encrinuraspis*, New Ordovician trilobites from New South Wales, Australia. *J. Paleont.* **44**, 881-887.

WHITTARD, W. F. 1955. The Ordovician trilobites of the Shelve Inlier, West Shropshire, Part I. *Palaeontogr. Soc., Monogr.* 1-40.

—— 1958. The Ordovician trilobites of the Shelve Inlier, West Shropshire, Part III. Ibid. 71-116.

—— 1961. The Ordovician trilobites of the Shelve Inlier, West Shropshire, Part V. Ibid. 163-196.

WHITTINGTON, H. B. 1950. Sixteen Ordovician genotype trilobites. *J. Paleont.* **24**, 531-565.

—— 1952. The trilobite family Dionididae. Ibid. **26**, 1-11.

—— 1957. Ontogeny of *Elliptocephala*, *Paradoxides*, *Sao*, *Blainia*, and *Triarthrus* (Trilobita). Ibid. **31**, 934-946.

—— 1959. Silicified Middle Ordovician trilobites: Remopleurididae, Trinucleidae, Raphiophoridae, Endymioniidae. *Bull. Mus. comp. Zool., Harv.* **121**, 371-496.

—— 1963. Middle Ordovician trilobites from Lower Head, western Newfoundland. Ibid. **129**, 1-118.

—— 1965. Trilobites of the Ordovician Table Head Formation, western Newfoundland. Ibid. **132**, 275-442.

—— 1966. Phylogeny and distribution of Ordovician trilobites. *J. Paleont.* **40**, 696-737.

—— and HUGHES, C. P. 1972. Ordovician geography and faunal provinces deduced from trilobite distribution. *Phil. Trans. R. Soc. Lond. B*, **263**, 235-278.

B. D. WEBBY

Department of Geology and Geophysics
University of Sydney
N.S.W., 2006
Australia

Typescript received 3 January 1973